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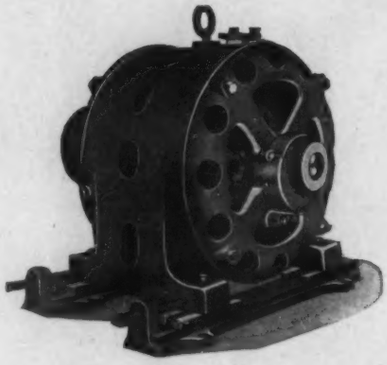

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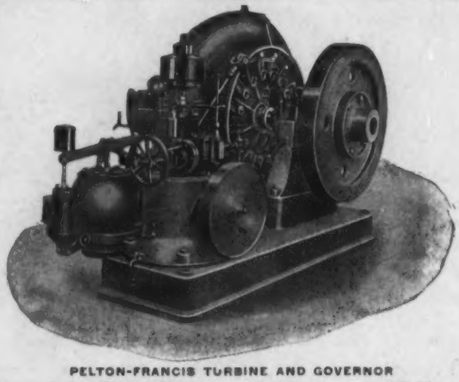

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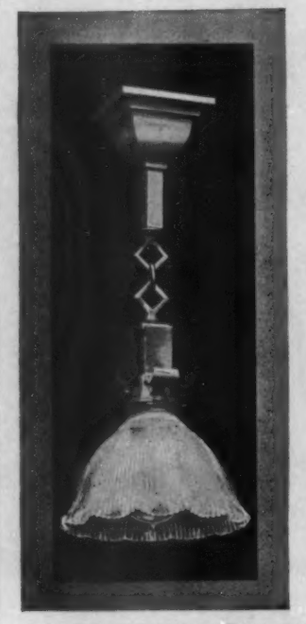

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POWER AND GAS
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VOLUME XXIII SAN FRANCISCO, NOVEMBER 27, 1909 NUMBER 22

ELECTROLYSIS[1]

BY WINFIELD S. WILLIAMS.

The subject of electrolysis, so vital to public welfare, as applied to electrolytic deterioration of underground metallic structures, due to the diversion of a portion of the return current from the single wire electric railway system, is at present causing and in the past has caused more diversity of opinion, both among experts and the public, than any other electrical problem. The great confusion of evidence created mainly by contradictory reports, is due to a lack of sufficiently sound theoretical and practical knowledge upon the subject. Many conclusions are unwarrantedly arrived at without a proper and full consideration of the phenomena involved. The theorist has no practical knowledge along the lines which he is supposed to advise, and he whose knowledge is based upon experience alone is ofttimes led to make unsound statements which are not consistent with well known laws of electricity and electro-chemistry. This confusion only tends to broaden the already unpleasant relations which, as a rule, exist between the owners of single wire street railway systems and the owners of underground metallic structures.

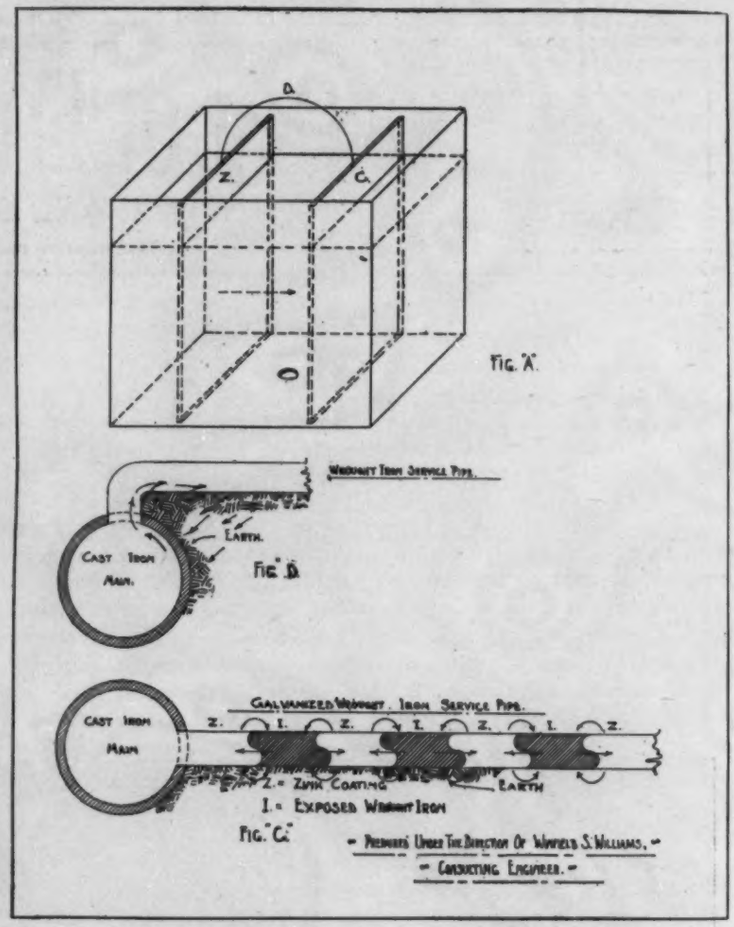
For a proper understanding of the action of stray electric currents on metallic masses buried in the earth, it has been thought well to give a brief and non-technical description of the influences at work.

Effects of Electrolysis on Gas Main Laying for Ten Years in Sandy Clay Soil.

For some time it has been known that if two dissimilar metals be immersed in a slightly acidulated solution, and metallically connected, a current of electricity will flow from one metal through the solution to the other, completing the circuit via the connection between the second and the first metals. The effect of this is to cause that metal, from which it flows into

[1]Report to Committee on Supervision of Public Improvements and Expenditures, Civic League of San Francisco.

the solution, to dissolve and lose weight. For example: In Fig. A, let Z and C represent respectively zinc and copper plates, both of which are immersed in an acidulated solution O, Z and C being connected by a conductor of electricity D. The flow of current will be indicated by the arrows, and the zinc plate will be gradually consumed in the solution. If the copper plate C be replaced by an iron plate, the direction of flow of current will be as noted above, and the zinc plate Z will as before be consumed, while if the zinc plate Z be replaced by an iron plate, the current will flow from the iron plate through the solution to the copper plate and will lose weight. The above illustrates the actions of a galvanic couple in which an electric current is generated at the expense of one of two dissimilar metals immersed in a solution. The direction of the flow of current will depend both on the metals immersed and to a lesser extent on the solution in which they are placed. Experiments show that if a plate of wrought iron be connected to one of cast iron and placed in a solution of soil taken from a street excavation moistened with water, the direction of current would be from the wrought iron plate through the solution to the cast iron plate.



In our water systems placed underground, we usually use wrought iron pipe coated with zinc for supply service connections and cast iron pipes for supply mains. If the soil be moist, a local current of electricity will be generated and will flow from the service pipe through the earth toward the cast iron main. The wrought iron service pipe will be gradually consumed, losing first its zinc coating and then its own structure. The zinc coating will protect the service pipe as long as it remains intact, for in a zinc-iron couple the direction of flow of the current is from the zinc to the iron. The action is illustrated in Figure B.

We may have a condition in which a service pipe (wrought iron), from which the zinc has in places been removed, connected to a cast iron main. This is illustrated in Figure C. In this case local currents will manifest themselves as indicated by the arrows. Closer circuits are formed from the zinc through the soil to the exposed wrought iron pipe and back through the material of the pipe to the zinc coating. As the current from the zinc to the wrought iron is of greater potential than from the wrought iron to the cast iron, and opposed, the curent from the zinc to the wrought iron will prevent the current from leaving the wrought iron for the cast iron. In this way the wrought iron service pipe will be protected, even though the zinc does not form a complete coating. A remedy suggested for the prevention of the corrosion of wrought iron service pipes by local currents consists in attaching metallically to it at frequent intervals plates of zinc so located that they may be renewed when necessary. The above will tend to show how metallic structures other than water pipes may be destroyed by local electric currents. So far local action only has been considered.

If, however, two iron plates are immersed in an electrolytic solution and an electric current from some outside source be passed from one through the solution to the other, the plate from which the current leaves for the solution will be gradually consumed, but at a greatly increased rate over that in the instance of a true galvanic couple. This action is illustrated in Figure D, in which A and B are two plates immersed in a solution and connected to the terminals of a generator C. The current will flow as shown by the arrows, with the consequence that A will be gradually consumed while B may or may not be affected, depending on conditions. If the above plates designated as A and B be copper and the solution be copper sulphate, the metal removed from plate A will become copper sulphate and be dissolved in the solution, while at plate B sulphate of copper would be decomposed and give up metallic copper as a deposit on the plate.

Plate B, under such conditions, would increase in weight nearly in the same extent as plate A was consumed. In the above the plate from which the current appears to leave is called the positive plate, and that one to which it appears to flow is called the negative plate. The plate that is consumed is always the positive plate. In the earth various pipes or buried metallic structures may be considered as positive or negative plates, surrounded by an electrolyte composed of the various salts of the soil dissolved by the rain, or other impregnated earth. The current causing electrolytic action (local action being not considered) may be

derived from the electric lighting or street railway systems.

With one exception, the several commercial utilizations of electricity as a medium of the transmission of power require a complete metallic circuit insulated from the earth. The exception is that of the grounded street railway with the single trolley. Leakage from power and lighting circuits may cause current to flow into the earth, but in electrolytic deterioration of underground metallic structures the grounded street railway only has to be seriously considered.

In the earlier days of street railway development, the electric system was operated with the negative side of generators connected to plates placed in the earth. It was soon found, however, that the current did not flow as freely through the earth as was expected. The next step was the use of the rails as a return path in connection with the earth. It soon became evident that the resistance of the rails as a return circuit could be decreased by the use of a mechanical bond placed between consecutive rails in addition to the connection made by fishplates. The next development was by the use of cast and welded joints. (It will not be the endeavor at this time to enter into the merits of the various forms of bonds.) The latest advancement is shown by the installation of heavy copper wires connected at intervals to the rails as return feeders. The above has been given for the purpose of showing the necessity of a return circuit of as low a resistance as possible and the means that have been used to accomplish this result. In addition to the rails, earth and return feeders, metallic structures placed in the earth will tend to act as a part of the return feeder system.

Thus we have: (1) The auxiliary copper return feeder circuit, usually placed on poles, but connected to the rails at certain points.

(2) The rails uninsulated from the earth.

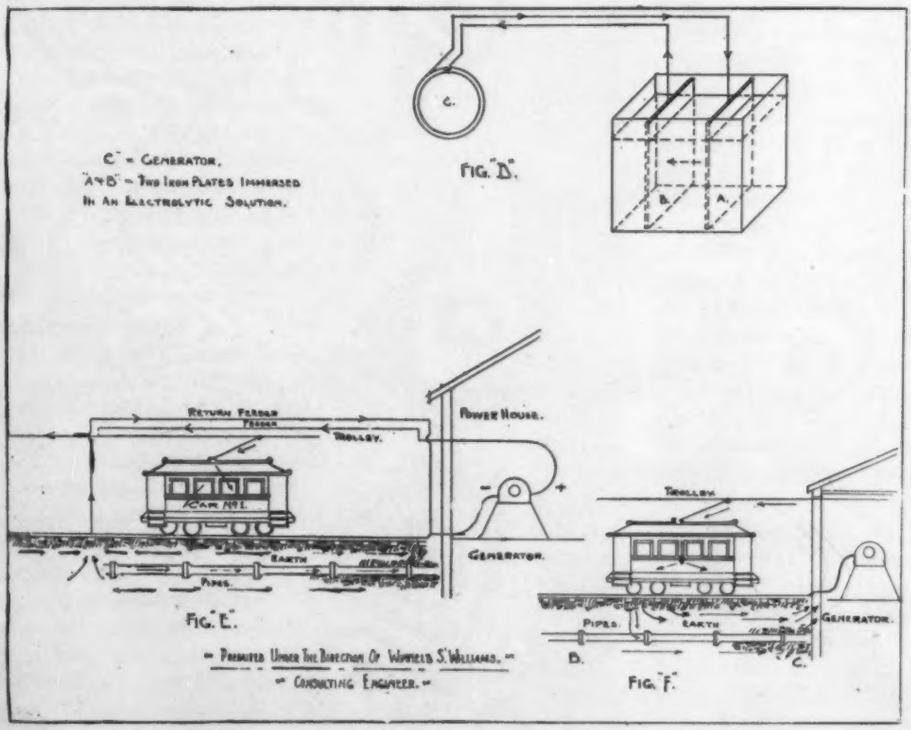
(3) The earth, particularly that portion in the neighborhood of the rails.

(4) The buried metallic structures, such as water and gas pipes, placed in the earth. These are shown diagrammatically in Figure E.

Since the various parts of the return circuit as enumerated above are in parallel the laws governing the amount of electricity flowing in parallel circuits must hold, namely, the current flowing in any section of a parallel circuit varies inversely as its resistance. Regarding the proper size of the auxiliary copper return, it should be of such dimensions as will offer but little resistance to the flow of the return current and should be tapped onto the rails at well selected points. The size in any particular instance will depend on the number of cars in use, and hence on the amperage of the return current. The effectiveness of any certain form of rail considered as part of the return circuit will depend on the thoroughness in which the joints between adjacent rails are made. The joints should be well constructed both from a mechanical as well as from an electrical standpoint, and should be of such a nature that they will not deteriorate with age. It is not necessary to go into details regarding the forms of joints, save that they should comply with what has been said; the main thing being that they should be of a permanent nature and of low resistance. Regarding the earth as a path for the return current it may be said that its conductivity will depend on various conditions, such as moisture, character of soil, etc., all of which may tend to make its resistance to the flow of current greater or smaller.

From an electrolytic standpoint, we know that where a current of electricity leaves the rails of the single wire railway system and passes into the earth, the electrolytes that lay adjacent to the rails and pipes split up electro-chemically into non-corrosive elements and acid-forming radicals. The corrosive radicals appear upon the surface of the rails and the non-corrosive elements appear upon the surface of the pipes. If, however, the pipes be electrically positive to the rails the current will pass from them into the earth and liberate the acid-forming radicals upon the surface of the pipe. Hence, if at any point the rails be electrically positive, they will be deteriorated, and if, on the other hand, the pipes be electrically positive, they in turn will be seriously corroded by robbing them of metal which will recombine in the various compounds of iron salts.

The acid-forming radicals consist chiefly of nascent oxygen and chlorine, which are very active in



producing corrosion. Since the electrodes in the case under consideration are of iron the counter electromotive force of electrical polarization is eliminated, there being no difference of electrical potential of counter electromotive force to contend with, making the situation from an electro-chemical situation far more simple than when dissimilar metals are involved. The rate of electrolytic deterioration of any piping system depends upon one general law, namely, the rate of deterioration is directly proportional to the product of the current in amperes and the time or duration of the current flow. The theoretical amount of iron passing from the surface of a buried underground structure in one year by a current of one ampere flowing from its surface is about twenty (20) pounds. With lead, for instance, the deterioration is three and one-half times as large. Consider Figure F. It is seen that the current will pass from the generator to the trolley wire, through the motor to the rails. Through the rails, earth and pipes it flows back to the power house. There are two paths open for it, one consists of the rails and the other a combination of the earth and the buried pipes. As has been noted, the current flowing through these two paths in parallel is inversely proportional to the resistance of these two paths. Therefore, in a general way, a considerable portion of the current will leave the rails at A, flowing into the water pipe at B, and will again leave the water pipe at C and enter the rails. Here, then, is an electric current flowing between metallic structures that may be called electrodes at places in the return path from the motor to the power house. All that remains, then, to promote electrolytic action is the presence of some solution which will act as an electrolyte. This is found in the earth. Referring to the diagram it can be seen that if there exists in the ground sufficient moisture and some metallic salt, electrolytic action will take place between the electrodes A and B and between the electrode C and the rails. The metals of this electrolyte will be deposited at B and on the rails, while the active part of the electrolyte will be found at A and C. Consequently, corrosion of the metallic structure may be expected at A and C and at all points where current is found leaving the metallic structure. At A the flow of current is such that there will be a loss of metal of the rails and at C there will be a loss of metal of the pipes. In either case the loss of metal will cause the resistance of the return circuit to be increased. The withdrawal of metal from the rails is not of such importance as that from the gas and water pipes, since they are under pressure. As the thickness of the metal of the pipe decreases, a time will come when they can not any longer withstand the pressure from within and bursting will result. In the case of cast iron we find that on account of the presence of graphite carbon, which is not acted upon by nascent oxygen and nascent chlorine, the deterioration is not so rapid as is the case of wrought iron. When tar coated cast iron pipes are electrolytically affected, a tubercular formation is formed, resulting in pitting of the pipe. The depressions are the result of greater current density at the places in question, caused by the adjacent soil coming into closer contact with the surface of the pipe. An untarred cast iron pipe suffers more uniform deterioration than does a tarred cast iron pipe. If the pits be arranged longitudinally a sudden rupture is liable to occur, but if they are not arranged in any particular way a clean eaten hole is formed upon rupture. It has been found that ordinarily calked cast iron pipe rarely ever carries more than a very small portion of the total current leakage from the track of a single trolley system. The earth usually shunts from 10 to 40 per cent of the return current, which, however, spreads out into vast dimensions, being governed by the resistance of the neighboring section of the earth. Throughout the area which this escaping earth current occupies it encounters numerous pipe lines. In the outlying or negative districts the current densities are light, but in those districts where the current returns to the rail the current densities increase, causing much deterioration of pipes in that section. We may have sections of a piping system affected by the currents passing from the earth to the rails in a vertical direction, but with no current flow along the length of the pipe. It is from current flowing as above defined rather than along the pipe lines that increases electrolytic deterioration and makes the subject confusing,

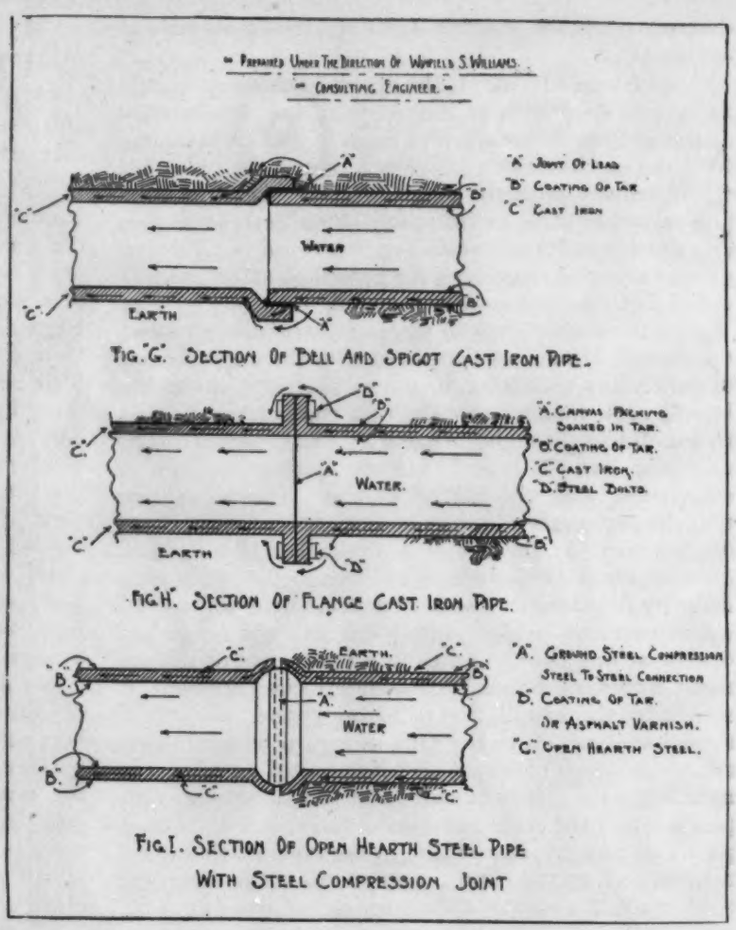


Fig. G. Section Of Bell And Spigot Cast Iron Pipe.

Fig. H. Section Of Flange Cast Iron Pipe.

Fig. I. Section Of Open Hearth Steel Pipe With Steel Compression Joint

and for this reason the installation of insulating joints is practically useless in preventing electrolytic corrosion upon pipe lines. As will be shown, the method of calking presents a joint of high resistance much greater per unit of length at the joint than in any other section of pipe lines.

Greater current than ordinary will flow through the pipes by the presence of one or more joints of high electrical resistance in the track. Hence ,electrolytic action in any metallic structure which may occur in the earth path of the return current is almost directly proportional to the faultiness of the construction in the rail return. Regarding the electrolytic action that takes place in a section of pipe we may consider Figure G, which shows sections of two adjacent cast iron pipes, and Figure H, which shows sections of two adjacent cast iron flange pipes. A heavy coating of tar varnish, which is a non-conductor of electricity, is placed with a thickness of one- sixteenth inch both on the inside and on the outside of the pipe. At A is shown a joint of lead, which as time goes on is chemically changed to an oxide of lead, which in turn is a non-conductor of electricity. We will assume that portion of the return electric current that traverses the pipe to flow from the right to the left, as shown by arrows. At the bell-and-spigot ends of two adjacent pipes it meets with a section of high resistance. A small amount of current will flow via the high resistance joint, but a larger amount will pass from one pipe to the other via the earth. As previously shown, the earth may be considered as an electrolyte and the current in passing from one pipe to the other via the earth will withdraw metal from one pipe in the direction of the other, as shown by the arrows, thereby weakening the pipe at this point.

Figure H shows the section of a flange cast iron pipe with steel bolts and tarred canvas packing. The steel bolts are affected by electrolysis much more than is cast iron, and consequently the steel bolts will break down faster than the adjacent cast iron of the pipe. This has been one cause of the somewhat rapid deterioration of the high pressure piping of the Philadelphia system. In contrast to the above is shown in Figure I a section of open hearth steel pipe with steel compression joint. At the joint no insulating paint is used, and as a steel to steel surface is present the resistance to the flow of electricity at the joint is the same or nearly the same as in other sections of the pipe line. Baltimore, Md., is installing this system of piping for its high pressure fire protection systems. The maximum length of heavy cast iron pipe that is considered economical to handle is twelve (12) feet, necessitating a joint of high resistance spaced throughout the pipe line at the above distance apart, whereas with steel pipe sections of thirty (30) feet or even larger can easily be handled. It will thus be seen that the number of joints is materially decreased, and as has been explained, their resistance is no greater per unit of length than that of any other section of the pipe line. The object of going into detail regarding the electrolytic action possible in a section of pipe is to obtain a clear idea of such actions, not however because it is general, for practice has shown that usually it is not. In the socalled "drainage" method of attacking the electrolytic corrosion problem where the pipes are made to carry current we may have such electrolytic deterioration at the joints, as has been noted above. The defects of the "drainage" method are considered later.

A complete investigation of the deteriorating effect of electrolysis necessitates a complete electrical survey of the piping system under every day operation of the street railway system. To do this it is not alone necessary that volt meter readings should be carefully taken, showing difference of electrical pressure between the pipes and the rails, but also resistance readings should be made, giving the resistance of the path of flow of the electricity in the piping system. From this data the value of the current in the piping system at various sections can be calculated. For the proper investigation a number of portable instruments, should be used, and readings taken at least every 500 feet of the piping system. The data so obtained can be plotted and the two areas, positive and negative, can be easily ascertained. From the point of destruction of the piping system those sections which show where the iron is being removed from the pipes are of importance. It is absolutely useless to take only difference of pressure readings and likewise useless if but comparatively few readings are taken.

The best and safest plan to prevent the evils of electrolytic deterioration is to avoid the ground circuit. This can be best done by the adoption of the double trolley wire. The cities that use this are Cincinnati, Ohio, and Washington, D . C. Nevertheless, there may even with this system be some leakage, but the electrolytic corrosion caused should be trivial. The greatest impediment in the installation of the double trolley is, of course, its cost. It appears that the single trolley has come to stay, and with it a certain state of electrical affairs naturally resulting from its use. Perfect immunity from electrolytic corrosion can not exist in cities where the grounded system is used. It is now agreed among railway engineers that the evils of electrolytic corrosion can be so reduced that the owner or owners of underground metallic structures will have little cause for complaint. The most important thing to be done is to increase the return circuit to the highest available efficiency, making the electrical resistance so low by perfect bonding of rails and the installation of return feeders that little current can be diverted into the earth and upon the various underground metallic structures. To do this requires skill and expense.

In some cities the underground metallic structures are connected, usually in the vicinity of the power house, to the rails or negative side of the generator. The amount of current that the pipes will carry after such connections are made will be greatly increased, the conditions depending upon the efficiency of the bonding. Its harmful effects also depend upon the nature of the material of the pipe and the efficiency from an electrical standpoint of the joints. The greatest danger of connecting the piping system to the rails is that it will establish positive areas in some other section with very serious results. Insulated pipe joints have been proposed to lessen and cure the evils of electrolytic corrosion, but it is nearly unanimously agreed that it is a makeshift. Of course, they prevent the flow of current along the pipe line, especially when

newly installed, but they do not prevent the flow of current from passing around the joints through the earth; hence, we see electrolytic corrosion in systems where they are installed. It is the earth currents that pass to, over and from the surface of the pipe lines which bring destruction, regardless of the electrical resistance of the joints in a pipe line, whether purposely insulated or as in an ordinary lead calked joint. Tar coating and all ordinary forms of painting seem to succumb to the action of nascent chlorine, which is liberated by electro-chemical action.

From the above the following deductions may be drawn: Electrolytic destruction of pipes buried in the earth is due either to action of local galvanic currents or to the fact that a considerable proportion of the current used by single trolley street railroads to move their rolling stock returns from the car to the power house by way of the pipes. In the first instance the action is very slight, but in the latter case it often becomes an extremely serious matter. If the buried pipes in question were put together with joints of the same conductivity as the pipes themselves, and if the current could pass from the track to the pipes and from the pipes to the generator in the power house, over conductors of similar nature properly bonded, the mere fact that a current of electricity utilized them as a pathway would be of little moment. But where current flows through the earth and enters the pipes and at all places where it jumps around leaded or insulated joints and at points where the same leaves the pipes to flow to some other conductor, there is where trouble is sure to occur.

In San Francisco a high pressure fire protection system is about to be installed. Something over ninety-one miles of cast iron pipe, coated to a thickness of one-sixteenth inch (inside and outside) will be laid, practically all of which is to be in territory affected by return currents from the street railway system. Leaded joints of high resistance, as compared to the iron of the pipes, are to be used throughout. The nature of the soil in the major portion of the territory is either sand or clay, carrying considerable water. In the lower section of the city, where made ground is encountered, will be found an abundance of salt water. Here there are found the elements which will hasten electrolytic deterioration, provided leakage current from the street railway be present. It is not to be presumed that the system in operation in San Francisco is any different in this respect than those operated in other cities. Also a glance at the frontispiece made from an actual photograph taken in St. Louis, Mo., will convince the most casual observer that where cast iron pipes become so soft on account of electrolytic deterioration as to admit of wire spikes being driven into them, the situation is grave indeed.

The high pressure fire protection system is being constructed at an expense of approximately $5,000,000. The pipes are to withstand the pressure of 300 pounds to the square inch. The protection of property from fire is at stake; therefore, steps should be taken at once to reduce electrolytic deterioration to the minimum.

Suggestions that will, if followed, produce the best results are:

(1) A complete survey to be made, consisting of volt meter readings, resistance of path of current in earth and current values in pipes, earth and rails; same to be made as soon as the system is installed, and at least once every year thereafter.

(2) A thorough examination of the bonding of the railway system and the installation of the necessary copper cables as ground returns, thereby shunting the current from the earth and underground structures.

(3) The non-installation of any connection between the rails and the pipes, as well as the non-installation of insulation joints in the piping system.

CURRENT COMMENT

Examinations for second-class steam engineer is announced by the United States Civil Service Commission on December 15, 1909, to fill two vacancies in the position of assistant engineer at $1080 per annum each, National Museum, Smithsonian Institution, and vacancies requiring similar qualifications as they may occur.

The Pacific Coast Electrical Exposition will be held in San Francisco as scheduled from January 29 to February 5, 1910. The executive committee states that the burning of the Coliseum, in which it was to have been held, will make no change in the plans for giving the Exposition. Negotiations are now under way for a new location, notice of which will be given later.

Electrolytic removal of rust has been patented by C. W. Danforth and Noble Jones of Sharon, Pa., in a "process for electrolytically removing iron oxide scale" from the surface of iron and steel which consists in placing the same in a solution of sodium bisulphate and of passing to the metal as a cathode a current of not less than seven amperes per square foot, maintaining the solution at a temperature of not less than 40 degrees C.

Courses in the Conservation of Natural Resources are to be given at the University of Michigan in connection with the engineering department of the university. The course will be begun at the January semester and will lead to the degree of master conservation engineer. The University of Wisconsin is also to have a conservation course this year. The course at Wisconsin will be under the direction of President Charles R. Van Hise, who was formerly head of the department of geology and has been a member of the National Conservation Commission.

Examination for mechanical draftsman is announced by the United States Civil Service Commission on December 14-15, 1909, to fill a vacancy in the position of mechanical draftsman (male), $1,500 per annum, Engineer Department at Large, Portland, Ore. The examination will consist of machine design, shop work, drawing and training and experience. The appointee will be expected to design the details of simple but heavy machinery and castings; should be familiar with machine shop, foundry, and forge work; should have had some experience in the drafting department of a machine shop; should be able to determine the dimensions of machine parts when the conditions are given, and calculate the stresses and weights.

DAMAGES TO TELEPHONE COMPANIES BY BUILDING THROUGH ESTABLISHED LEADS.

BY EMERSON W. READ.

The questions of construction of telephone lines and lines of companies making use of electric currents, although primarily for the solution of the engineers, often involves the lawyer and an application of the laws. The various damages that result to telephone systems through leakage, conduction, induction, and contact, in the relation of telephone systems with other electric systems, are well known to the engineer and the lawyer and have caused much trouble in the course of the development of the various enterprises which rely upon the electric current for existence. Some of this damage results from lines of low voltage. The greatest trouble of the telephone company in its relation to other systems arises out of electric light and traction lines.

Disregarding for the time the questions of damage that arise from falling wires and grounding in the same territory used by another company, another field presents itself which relates to the "lead" above ground. It is now axiomatic that the company building subsequently to one already in the field must give due regard to under-building and over-building, the proper distance between adjacent wires, and insulation, both in the relation of company to company, and in the relation of company to community.

The courts have long held that the company which first lawfully installed its wires along a highway acquired certain rights by virtue of its priority in construction. These rights are determined by the needs and demands of the prior company and operate to prohibit subsequent construction under, over, or across its lines or lead which would interfere with the business of the prior occupant. These rights entitle the prior occupant to more than a clear lead for such construction as exists at the time the subsequent occupant begins construction. It must be remembered that the prior company will, in all probability extend its system, will add new cross-arms, and will string more wires. "The first established company is therefore entitled to a reasonable amount of space on its poles for new cross-arms and wires to meet this possible increased demand of the public."

However, the rule already stated cannot operate to prohibit another company from making use of the highway when the subsequent occupant can construct its system so as not to unnecessarily interfere with the prior occupant. Wires crossing and paralleling the wires of the company already established, lawfully erected, and not substantially interfering with the prior established lead are permissible and do not come within the general prohibitory rule. "One of the interferences with appellant's system of telephone which is charged against the appellee is that in many of the streets of the city appellee has erected its telephone poles and strung its telephone wires upon the same side of the street where the telephone poles and wires of appellant are set and strung, and that appellee has been guilty of overbuilding the poles, wires and telephone system of appellant; that is to say, that it has strung its wires above the telephone wires of appellant, instead of stringing them below the same. In other words, appellee is charged by appellant with "overbuilding" and "paralleling," as the terms are used by the expert witnesses. If the city has no right to grant the exclusive use of the street to one telephone company, and has the right to grant the use thereof to two or more telephone companies, then the right of a later telephone company, coming into the street, to place its telephone lines upon the same side of the street with the telephone company coming earlier therein, necessarily results as a matter of course. There are only two sides to each street, and, if there are more than two telephone companies, two of them must necessarily be on the same side of the street." "The proof shows that in the proper construction of overhead systems of wiring the different high potential systems should be placed on one side of the street by themselves, and the different low potential systems of wires should be placed on the other side of the street by themselves." (Chicago Tel. Co. vs. Northwestern Tel. Co., 65 N. E. 335).

The method referred to in the extract above, "overbuilding," has occasioned other decisions. The courts have shown themselves ill-disposed to rule that such over-building or under-building is the proper method, although there are in existence decisions wherein courts have ruled that, in the cases before them, overbuliding should have been the method employed. Citing from one of these cases (N. W. Tel. Exchange Co. vs. Twin City Tel. Co. 95 N. W. 460) where an injunction issued restraining a telephone company from underbuilding the plaintiff company, we find "It is the common practice and usage in the construction of telephone lines and wires in urban localities, whenever one line passes another at street intersections, for the party desiring to pursue that course subsequent to the use and location therein by a prior occupant, to be constructed above the lines previously established and maintained." But it is not always desirable that subsequent occupants of a street overbuild. In the case of the Chicago Tel. Co. vs. N. W. Tel. Co. the plaintiff company applied for an injunction to prevent the subsequent company from overbuilding its system. In cases where the lower wires are high potentials it is now considered unsafe telephone construction to overbuild with telephone wires. It is not a violation of safe telephone construction, however, to overbuild systems of low potential where the system below is low potential, also.

"If one company's wires are built too near those of another company, or if the wires of a subsequently erected system pass through an established lead in such a way as to be unlawful and dangerous, the company first in position may protect itself by securing an injunction or restraining order from the court. It may likewise by mandamus require the company subsequently coming into position to take proper steps against interference and danger and damage. For any damage sustained it may also bring an action to recover.

Increase in street railway fares on the Pacific Coast can be but a matter of a few years. Many Eastern roads have been forced to this course, and now the interurban road between Tacoma and Seattle has increased its rates to two cents per mile.

SOME PHASES OF TRANSFORMER REGULATION.

Discussion by members of the San Francisco Section, American Institute of Electrical Engineers of paper read by W. A. Hillebrand and S. B. Charters Jr. and published in the JOURNAL OF ELECTRICITY, POWER AND GAS, November 20, 1909. The following members participated in the discussion:

Geo. R. Murphy, Chairman, Electrical Engineer, Pierson, Roeding Co., San Francisco.

H. Y. Hall Jr., Assistant Electrical Engineer, Southern Pacific Company, San Francisco.

F. E. Geibel, Engineer with Southern Pacific Company, San Francisco.

W. F. Lamme, District Engineer, Westinghouse Electric & Manufacturing Company, San Francisco.

B. G. Lamme, Chief Engineer, Westinghouse Electric & Manufacturing Company, Pittsburg.

A. H. Babcock, Electrical Engineer, Southern Pacific Company, San Francisco.

J. W. White, Electrical Engineer, San Francisco office Fort Wayne Electric Works.

S. G. Gassaway, Assistant Electrical Engineer, San Francisco office General Electric Company.

W. A. Hillebrand, Stanford University.

C. L. Cory, Professor of Electrical Engineering, Universiy of California.

F. V. T. Lee, Assistant General Manager Pacific Gas & Electric Company, San Francisco.

G. C. Holberton, Engineer of Electric Distribution, Pacific Gas & Electric Company.

H. Y. Hall Jr. (Owing to a sudden summons East Mr. Hall was unable to revise his manuscript. It will be published after Mr. Hall's return).

F. E. Geibel: The paper tonight has been very interesting, more so because we have had actual tests from which the conclusions have been drawn. As explained, the action of transformers in groups, or in banks, depends on the action of the single phase transformer, and the authors have touched briefly on the single phase transformer and meter potential transformer before going to the banks.

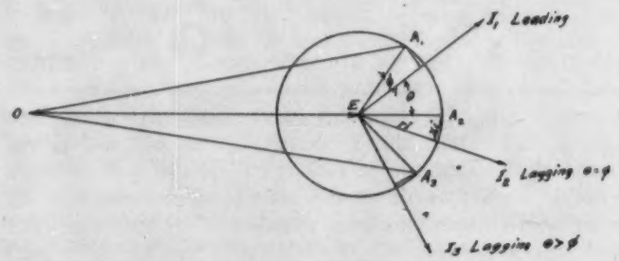
Unbalancing on the banks of transformers, as we have seen from the paper and discussion, is largely taken care of by the induction motor and synchronous apparatus. Again, in the case of power transformers, or transformers for delivering power, we are not so much concerned in the phase angle difference; what we want on the other side is voltage, and with as little drop as possible. As the regulation is affected at high power factors mostly by the resistance, and at low power factors mostly by the reactance, in a well designed transformer, both are kept as low as possible. In the case of the meter transformer, however, the phase angle difference between the secondary and primary e. m. f.'s plays a more important part and affects considerably the wattmeter readings.

The authors have found that, in the meter transformer under test, the equivalent resistance is about twice that of the equivalent reactance. Since the power factor of an a. c. circuit is the cosine of the angle whose tangent is .. , we have for the power factor of this transformer, 0.91 approximately.

In the accompanying diagram OE represents the secondary e. m. f, EI_1, EI_2 and EI_3, the secondary current at different power factors, and A_1O, A_2O and A_3O the corresponding primary e. m. f.'s. From the figure it is seen that in passing from leading current to lagging current, the angle of lag exceeding the angle of lag of the transformer, we pass from a condition of lagging to a condition of leading phase angle difference between primary and secondary e. m. f.'s, the two e. m. f.'s being exactly 180 degrees apart when the power factor of the load is made the same as the power factor of the transformer.

The power factor of a meter load is approximately 0.75 to 0.8 and on the meter transformer under discussion, a load of this character would give a condition of leading phase angle difference. Thus, while the poor regulation of the transformer would cause a wattmeter to indicate low, the leading phase angle difference decreases the angle between current and potential and causes the meter to indicate high—the two effects to a large extent neutralizing.

The meter transformer, although not showing up so well when regulation alone is considered, has been found to be very accurate, especially when used on loads for which they have been designed.



In the July number of the Proceedings Mr. Robinson has gone into this matter very thoroughly and has also brought into account the phase angle difference of the meter itself.

W. F. Lamme: The problem of transformer regulation is usually a very important one. As noted in tonight's paper, there are three elements to be considered:

First—The ohmic resistance.
Second—The inductance.
Third—The leakage flux.

In the paper is given a case in which large flux leakage takes place, with certain connections. But in every transformer there is a slight leakage between the primary and secondary coils, and this leakage is different in different transformers. And even in different arrangements of coils in the same transformers. The more closely interlaced the primary and the secondary coils are, the better is the regulation. And vice versa. In other words the more perfectly the magnetic flux set up by the primary coils are forced through the secondary coils, the better the regulation. This is, or should be, a question of considerable interest to all engineers. But, I believe, definite information upon the subject is largely confined to factory circles.

It is interesting to study the regulation of transformers with non-inductive and with inductive load. With a non-inductive load the regulation of a transformer is, of course, nearly equal to the ohmic drop, and the inductance has little effect. With an inductive load the inductance of the transformer comes into effect, and the effect of the resistance is lessened depending upon the power-factor of the load. From the above it may be inferred that the regulation of two transformers may be different with non-inductive load, and nearly the same with inductive load.

In recent years more care has been given to this question of regulation for lower power factor. The point just mentioned is best illustrated by two sets of curves. One showing the regulation of a series of transformers from one to fifty kilowatts operating with non-inductive load. The second curve showing the same transformers operating with an 80 per cent power factor load. In these sets of curves are three types of transformers. A core type, a shell type, and one of the newer types of transformers. At 100 per cent power factor you will note all of the types agree very closely in regulation, taking them size for size. But the regulation is poorer the smaller the size of the transformer. All this is natural, and to be expected, for economical design limits us to this condition. But at 80 per cent power factor the regulation of the same sizes are wide apart. And the regulation of the older type is quite erratic, whereas the regulation of the two newer types are not so erratic. Also note that the newer types have nearly the same regulation from the smaller to the larger sizes.

As to transformers for operating meters, we note from the

paper that these transformers are compensated for the conditions under which they are supposed to operate. This is important. If the transformer is compensated to operate say, one wattmeter, correctly, the same transformer will not operate two wattmeters correctly. And in the second case there may be an error of several per cent. Therefore, in the purchase of such transformers, it should be the practice of the party purchasing the same to name the conditions of operation.

Combinations of transformers to change from three phase to two phase, or from two phase to three phase, are made at the expense of regulation, as well as at a loss in efficiency. By the example in the paper, you see that it is important to know how to make some of these combinations properly. Otherwise the regulation and losses will become excessively bad. And, as a result, there may be a burnout of one of the transformers.

Mention was made in the paper of unbalanced primary voltages and their effect on the secondaries. This is a very important matter, especially in power transmission work. In such work we rarely see balanced conditions on the delivery line. Sometimes the unbalancing is very bad. I have in mind one case of a 30 h. p. 3 phase induction motor operating from 3-10 k. w. transformers. One of the three transformers burned out without apparent cause. Our investigation showed the division of load between the three transformers as follows: First—14 kva., second—10 kva., third—6 kva. The 14 kva. transformer burned out, due to unbalanced condition of line. The above transformers were at first connected delta to delta. They were changed to delta primary, star secondary. After which the loads divided much better than they did at first.

B. G. Lamme: The authors of the paper of the evening have called attention to the unbalancing or distortion of voltage and phase which may be obtained with various unsymmetrical combinations of transformers. They have also stated that induction motors tend to reduce such distortions. It may be added that synchronous motors and rotary converters also tend to reduce the distortion. But all such correcting effect is obtained at a certain expense, usually in the capacity of the correcting apparatus.

Distortion of phase, and of voltage, both tend to produce unequal currents in induction and synchronous motors, including rotaries. If one leg of a supply circuit is of higher voltage than the others, while the motor generates equal counter e. m. f.'s, current will so flow in the motor that the motor e. m. f.'s are distorted in the direction of the line distortion, while the currents tend to correct the line e. m. f. The limit is when the line and motor come to balanced condition with respect to each other.

This unbalancing in the currents affects the capacity of the motors. The total copper loss may not be greatly increased, but the losses in individual coils, or circuits, will be changed. At the limiting capacity of the motor, the heating of individual coils fixes the rating, as a rule, and not the loss as a whole. Any unbalancing in current, therefore, affects the heating of the individual coils, and thus reduces the limiting capacity. This is true for induction and synchronous motors. But for rotary converters the case may be still worse.

In rotary converters the armature copper loss is normally much less than with a corresponding d. c. machine, or if the rotary was run as a straight d. c. generator. This is due to the fact that the same winding is used for the incoming a. c. current and the outgoing direct current. Part of the a. c. input is fed directly in the d. c., while part is transformed to mechanical energy, and back to d. c. electrical. In consequence, when transforming 3 phase to d. c., the armature copper loss is only 57 per cent of straight d. c. operated with same armature, while with 2 phase (or 4 phase in reality), it is 38 per cent, and with 6 phase it is 26 per cent. But this 26 per cent loss is not uniformly distributed in the armature. The average loss in the various armature coils depends upon their position with respect to the tap offs to the collector rings. The highest loss is next to the tap off, this being about 60 per cent of d. c. Therefore, the coil next to the tap off is liable to be overheated under extreme condition of load.

If the power factor is not 100 per cent, then this loss curve is greatly affected. At about 95 per cent the loss in the tap off coil goes up about 100 per cent. And at still lower power factor it goes much higher. Therefore, a low power factor greatly reduces the ultimate capacity of a rotary, depending upon the size and general design of the windings, number of phases, ets. Unbalanced voltages or phases, due to unsymmetrical transformer combinations will have a bad effect on the capacity of any rotary, and care should be taken, with such machines, to furnish balanced supply conditions.

The fact may be of interest that 60 cycle rotaries, as a rule, can be operated at lower power factors than 25 cycle rotaries as normally constructed. This is not due to any peculiar merit of 60 cycles, but is due to the fact that 60 cycle rotaries usually have many more poles than 25 cycle, and if parallel wound, as is usually the case with large sizes, the smallest armature strap conductor which is safe for mechanical reasons, is much larger than necessary for electrical purposes.

It has been found in practice where unsymmetrical transformer combinations have been used for step up purposes, that a similar arrangement should be used for stepping down. For instance, if the Scott, or T combination is used to step up from 2 to 3 phase, then a T should be arranged for stepping down to motors, with the head of the step down T across the same wires as the head of the step up T. The same is true of other unsymmetrical combinations. In this way some of the inequalities cancel instead of accumulate.

In connecting unsymmetrical transformer combinations in parallel, there is usually a possibility of cross currents between them, unless all are arranged across the polyphase lines in a similar manner. Such arrangement tends to give a more symmetrical resultant secondary system.

In conclusion it may be said that all unsymmetrical systems should in general, be avoided. Such systems originate, as a rule, in an attempt to save in first cost of a system or installation, but in the end they are generally much more expensive than true balanced systems, when reduced capacity of apparatus, etc., are taken into account.

A. B. Babcock: What is the effect, practically speaking, of connecting to a 25 cycle circuit, a meter transformer which operates at a normal frequency of say 60 cycles? What is the effect on the error of the meter?

W. F. Lamme: We cannot give you certain figures on that matter, but the tendency would be that when you put the transformer on the lower frequency the iron is worked much harder, and there is an exciting current larger, and this will throw a different angle formed by the secondary, which will affect the action on your meter. Just how much that is, I don't know.

A. H. Babcock: Couldn't it be compensated for, ordinarily, with a practical meter?

W. F. Lamme: I think it could be. If you change from 25 to 60 cycles, the meter should be checked up.

A. H. Babcock: Would the meter run fast or slow? Suppose, for instance, a 60 cycle meter was put on a 25 cycle circuit, would the meter register more or less?

W. F. Lamme: It would register less.

A. H. Babcock: I asked the question because reports have been made of very small energy consumption of single phase apparatus on low frequency, so small in fact that the accuracy of said reports might reasonably be questioned. If the records were taken by means of meters designed to operate normally at high frequency, it seemed to me that an explanation for the low readings is obvious, provided these operating conditions would make the meters run slow.

W. F. Hillebrand: Perhaps I can indicate what would take place. This component *XI*, Fig. 2, of your transformer impendance is the reactance drop which varies directly with your frequency. If your meter was designed for 60 cycles and you put it on a 25 cycle circuit, that reduces this component in the

proportion of 25 to 60, which is 5/12. This reduces the transformer impedance and that would tend in certain cases to change the phase angle. For operation on high power factors it would tend to reduce the phase distortion.

J. W. White: In regard to Mr. Babcock's inquiry on the effect of frequency changes upon the accuracy of primary recording wattmeter and particularly upon a 60 cycle meter operating upon a 25 cycle circuit, I would say that in the first place the potential coil of the meter would probably burn out on account of the excessive current. The potential transformer might do likewise as the capacity of a 60 cycle transformer operating on a 25 cycle circuit is but 69 per cent of its

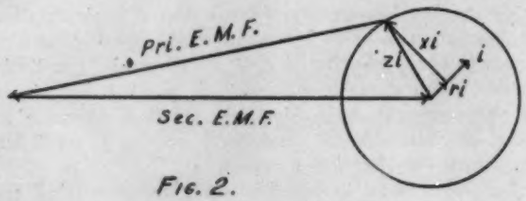


FIG. 2.

rating, due to excessive magnetizing current. However, if this did not occur the meter would *run fast.*

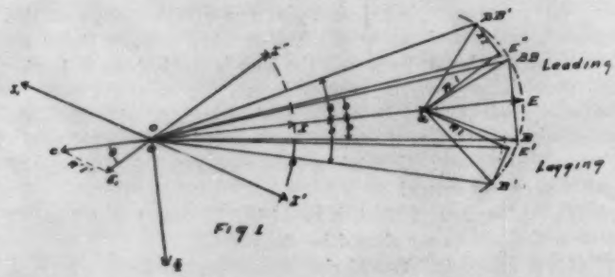
Considering first the potential transformer.

In a perfectly designed potential transformer the inductive reactance would be offset by the capacity effect and in Fig. 1, *OE* or *OB* would be the impresssed e. m. f. and *Oa* would be the effective e. m. f.

If, however, the phase angle of displacement is leading or lagging a condition will exist similar to *OB* or *OBB*. If operating on a lower power factor *RI* would remain constant with *XI* diminishing in proportion to the frequency. If *OE* and *Oa* coincide a lowering frequency would have no effect inasmuch as the inductive reactance is offset by the capacity effect and thus the effective e. m. f. would be higher and the amount of compensating effect in the transformer's secondary winding can be less.

If, however, the reactance effect in the transformer is leading or lagging to produce *aBB* or *aB*, then the phase displacement of the transformer is equal to (*BB.O.E*) or *B.O.E.*

If, as in Fig. 1 (BB^1 a^{11}) the power factor of the circuit (not the transformer) passes from leading current to lagging



current, the angle of lag exceeding the angle of lag of the transformer the angle of phase distortion with reference to the secondary is further increased, while on the other hand if the power factor of the circuit is leading and the power factor of the transformer lagging the two would tend to compensate and cut down the angle of phase displacement.

The same condition would exist if the opposite were true, *i. e.* if the angle of phase displacement of the transformer were leading and the power factor of the circuit were lagging the two would tend to compensate, while if the power factor of the circuit were leading the resultant phase angle with reference to the secondary of the transformer would be greater.

From the above it is at once evident that in lowering, the frequency *XI* would be diminished and whether leading or lagging would cause the angle *B.a.E.* to be decreased and thus reduce the angle of phase displacement.

From the above can be deducted that lowering the frequency of a potential transformer will tend to reduce the phase angle of displacement if leading or lagging. (This would, if anything, cause the meter to run faster.) If the transformer capacity is balanced by the inductance there will be relatively no change.

With regard to the regulation of the transformer and the effect of the resistance of the coils upon same let the line *O* represent the harmonically varying flux in the core. *Oa* represents the useful part of the primary electromotive force and *Oc* the total electromotive force induced in the secondary coil. The line *OI*, represents the secondary current and the line OI^{11} represents the primary current. The total primary electromotive force E^1 exceeds *Oa* by the amount *RI* (parallel to I^1) and the electromotive force *E*, at the terminals of the secondary coil falls short of *Oc* by the amount R^1I^1 (parallel to I_1).

When the angle *O aOI*^{1} is nearly zero (secondary receiving circuit non-inductive) then *RI* and R^1I^1 are nearly parallel to *Oa* and *Oc* respectively, so that *Oa* is much less than E^1 in value and E^1 is much less than *Oc* in value. On the other hand, when the angle *O* is nearly deg. (secondary receiving circuit containing a large inductance or a condenser) then *RI* and R^1I^1 are nearly perpendicular to *Oa* and *Oc* respectively, so that *Oa* is nearly equal to E^1 in value and E_1 is nearly equal to *Oc* in value. Therefore the regulation of a transformer is largely affected by coil resistance when the secondary receiving circuit is non-inductive, but scarcely at all affected by the coil resistance when the secondary receiving circuit contains a large inductance or a condenser.

This accounts for the even regulation curve shown by Mr. Lamme illustrating the regulation of the Westinghouse Type S. transformer operating on low power factor, and this is characteristic of any type of transformer (multiple) operating under the same conditions.

With regard to the operation of the meter on 25 cycles refer to Fig. 2.

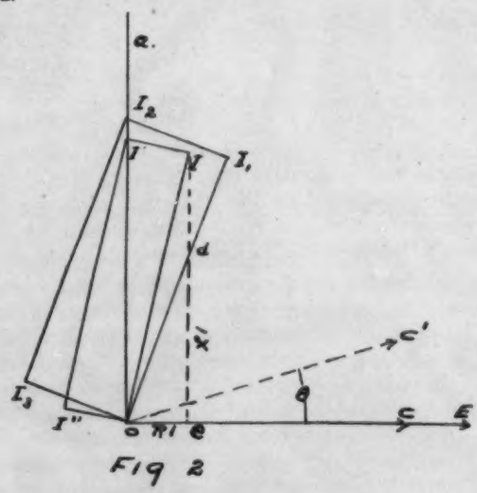


FIG 2

Let *OE* = Impressed e. m. f.
OC = Current non-inductive.
OC^1 = Current inductive.
OI = Current in potential circuit.
OI^{11} = Current in lagging coil.
OI^1 = Resultant current effect in potential circuit.

From the above it is at once evident that with a lowering frequency the impedance of both the potential and lagging windings will be decreased and the current flow, therefore, increased, thus increasing OI^1, causing the meter to run fast.

In addition to this it is also evident that with the decreased frequency the reactance factor of the potential circuit, *i. e.* XI^1 will be decreased 5/12, *i. e.* 25/60, making *XI* equal to *de* instead of *IE*. This will bring the angle of lag of the potential winding to OI_1 making it necessary, therefore, to add an increased effect

on the lagging coil to bring the resultant effect back to I_2 as the recorded power of the meter is equal to $OC \times OE \cos O$ and if the meter is not corrected it is therefore evident that with OI^1 increased and an error introduced equal to IOI_1 the correction factor would be cos $IOI_1+OI_2—OI^1$. In commercial service a pertinent example is noted in meters designed for operation on both 140 and 60 cycle circuits, which are double lagged, one coil being left open circuited on 140 cycles but short circuited through resistance when operating on 60 cycles.

From the above, therefore, three points are evidence:

A. A lower frequency will reduce the error of phase displacement in a transformer except wherein a unity power factor condition exists in the transformer winding. In this latter case there will be no change.

B. The regulation of transformers is vitally dependent upon resistance of its windings and its relative regulation is not effected as greatly on low power factor as in comparison with high power factors.

C. Integrating meters operating on lower periodicities than that for which they are designed will run fast and the effect of a lower frequency on the primary transformer for such a meter will be cumulative with that of the meter itself.

S. G. Gassaway: I was somewhat agreeably surprised with the paper tonight when the gentleman did not allude to a lot of mathematical formulae, which we expect to get from one coming from the University. The speaker tonight mentioned the V and Scott connections. The power factor is 86.6, and that has another meaning if you will first consider it. It means that if the load has a power factor of 100 per cent the power factor in these transformers is 86.6. In other words, you have approximately 15 per cent greater transformer capacity than your capacity of the load connected. In the "T" connection you have to have 92.8. In other words, you have something like 8 per cent more kilowatt capacity after you have the load connected.

The regulation of a transformer is really a sort of the measure of the care in which it is constructed. A more carefully constructed transformer has better regulation. Regulation is important in the transformer that is being used for lighting, because the lights vary greatly with the regulation. This can be done carefully by means of magnetic regulation. In condenser work where regulation is not so important because it can be taken care of by the reactive coils in series and allow for line drop, and so on, and get any regulation desired. Likewise in motor generation the regulation is not important in the transformers. Regulation depends on a number of factors, one of which is the reactance or impedance of the transformer. If the transformer is not carefully constructed, and there is considerable flux leakage that means the impedance is higher, in other words, poor regulation.

In the smaller sizes of transformers, we find the general transformer is of the core type, because it is cheaper made and it is lighter, but it has not in general as good regulation as a transformer of the "shell type." The reason for that is obvious, because in the "shell" type there is a great opportunity for interlacing the coils, though there is another reason for using the "shell" type, especially in larger transformers. It is necessary to divide the coils up more to prevent hot spots forming in the transformer and allow for better ventilation.

In some of the first transformers that were designed they experienced trouble with regulation, in some instances because of improper design, excess tanks, etc., being located too close to the windings—that is, concerning large flux leakage. A number of experiments were carried out, and they found that if these tanks were placed possibly three inches away from the coils they have no effect on the flux leakage.

The impedance of the transformer varies greatly, with the spacing or arrangement of the coils. Some experiments were made on the core type of transformer along the lines of varying impedance, and it was found that impedance could be varied from 2.4 per cent to 150 per cent by spacing the coils. We found that when we had all the primary coils on one leg, and all the secondary coils on the other leg of he transformer, that the impendance increased until we reached as high a figure as 150 per cent, depending on the number of coils and how well those coils themselves were placed on the transformer.

The regulation of a transformer has another feature to be considered, because we know the load divides up amongst transformers, according to the relative admittance, I believe it is called, which is commonly taken as the kilowatt capacity, divided by the impedance force, or the percentage in impedance force. As I said, the regulation depends on the impedance, therefore, if the impedance is large, the regualtion is poor, the relative admittance would be small, and we find that the transformer does not take its proper share of the load if it is arranged with transformers that have higher regulation.

I am very much interested in the paper this evening because it has given us an opportunity to understand the regulation of the transformer in a much broader sense than we do ordinarily. Summing up what has been said by the different men this evening it may be said that the regulation of a transformer, except as regards the change of the load, depends upon the resistance and reactance, and, by the way, reactance does not always mean inductive reactance, but it may mean condenser reactance as well. The regulation of a transformer, again depends upon leakage. An ideal transformer would be one in which the primary turn and each secondary turn occupy exactly the same physical space.

The paper this evening has interested all of us because it takes up the transformer from two different points; one, the transformer which is used for meter purposes, that is the potential transformer, and the other, the practical transformer, which Mr. Lamme has chosen to call, the unsymmetrical transformer.

A number of people in this room probably remember the series of tests made about two years ago where it was decidedly important to determine the accuracy of meters working not on 60 cycles, but on 50 cycles; where the current was to be 10,000 measured volts; where the power factor would vary between 100 per cent and 80 per cent and where the magnitude of energy was to be about 80 power factor, about 5,000 kilowatts.

The checking of meters was a simple matter, but the checking of potential transformer meters, and series transformers was an entirely different matter, inasmuch as in this particular case an error of about one-half of 1 per cent represented a loss or gain to the company of about $5000, accuracy was of some consequence.

To get at the method of determining this cause of phase relation of primary and secondary transformers of one manufacture and one of different manufacture, they were sent to the bureau of standards, and these transformers were operated not exactly at 60 cycles, but at 50 cycles, 48 and 52 cycles, and were connected as per instructions at the bureau of standards with reference to the Weston 150 volt 200 ampere indicating instrument, and also each transformer of its particular type to a 5 ampere watt meter that was used to measure the power. When these results were turned over to the company having charge of the tests it was found that the capacity of potential transformers had a great deal to do with the regulation, in other words, it determined that while one transformer had a great deal of insulation the other one did not have so much.

Answering Mr. Babcock's question, I should say that it was exceedingly dangerous, and subject to a very great error, to use a transformer and meter which was designed for 60 cycles on a 25 cycle. In the first place you are running a very great risk of burning out your potential transformer, but under any circumstances I doubt very much whether unless you knew definitely the curve showing the relation of the phase angle and the power factor that you could ever tell whether your meter was reading fast or slow. I am not quite sure that under some factors the meter would read fast and under others the meter would read slow.

F. V. T. Lee: The trouble particularly in regard to two phase and three phase or "T" connection has been well known in

the past, but I think this is probably the first time that a good many of us have had an opportunity of having somebody explain the true inwardness of the trouble. I remember one case that may be of interest where a plant was installed in the northern part of California, and for reasons of economy it was necessary to use three phase transmission. It was desirable to take two phase machines and connect them for three phase with the "T" connection. For some reasons it was necessary to use two phase motors. Some strange results were obtained, and what really happened was exactly as illustrated by the authors this evening. Unfortunately the winding of the generator did not allow for adjustment and the result was that special generators had to be built, which overcame the trouble, and when received from the factory the generator leads and the motor leads were all carefully tagged as to how they should be connected, so no mistake could be made.

Those days have gone by, but it is necessary to have papers of this character, so that those who have not given it special attention will look out for it, and those who have met the trouble will see the solution. These academic papers really should not be stigmatized as being academic, for the reason that they come from the University, where they have the time and opportunity to give these problems theoretical treatment which those in practice haven't time to do.

G. C. Holberton: Apparently the discussion of the paper has shown us that there are errors of regulation. The author referred to regulation of power transformers, or lighting transfomers such as we are using in practice, and that particular regulaion is a matter that we can watch and if it is a very serious thing we notice it, but in the matter of transformers used for meters we cannot. I think for that reason we should go into it even further than has been gone into tonight. In the discussion tonight, as I take it, it has been brought out that there are errors, all of which are over one per cent. If these errors are cumulative we may have an error of several per cent, which I am safe in stating we cannot determine in the ordinary way. If we have two or three different kinds of errors, any one of which amounts to over one per cent, we are getting into very serious condition. It is no uncommon thing in the present state of our business to have bills running about fifteen or twenty thousand dollars monthly. When there is an error of two or three per cent, it is a very serious matter. I don't think the ordinary meter test is capable of making an accurate test involving the current transformer and the potential transformer. The apparatus would be too bulky to carry around. I think it is necessary for some one to take up the subject from a practical standpoint and make these tests, which have been made at laboratory—make them under practical conditions.

W. A. Hillebrand: I have only one thing to say, and that is with reference to Mr. Lamme's remark about the effect of the power factor on the capacity of the converter, especially in the heating of the coils near the point at which the tap is brought out. Mr. Charters and I spent about three months last year investigating the behavior of induction and synchronous motors under various conditions. These were small machines, to be sure, not over 10 horse power at best, but they showed the power factor to be extremely sensitive to even slight variations in either amount or phase relation of the applied electromotive forces much more sensitive than might be expected from the inconsiderable current unbalance that occurs under these conditions.

If there is any one who would like to know about that method of measuring the angle of phase shift in potential transformers, I would be glad to explain it to him. I hardly think I can do so here very well for the lack of a blackboard.

The Electric Storage Battery Company of Philadelphia, has issued a most attractive publication on the "Exide" Sparking Battery. It contains a complete description of their ignition cell and a double page illustration showing its entire construction.

DIARY OF AN UP-TO-DATE MAN.

Some people think it costs a lot of money to be thoroughly well groomed and up-to-date, but Charles Pinkham Jones—everybody knows "Pinky" Jones, the "pink of perfection," his lady friends call him—Mr. Jones, as we were saying, keeps a diary that includes an expense account with a glimpse of which your correspondent was favored the other day, and from it he is able to give exact figures as to what it costs a bachelor, who uses modern labor-saving appliances instead of a valet, to present himself every morning at the bank, the perfect pattern of a well-groomed man. Here is the record for an average morning:

	Electric current k. w. hours.
"Rose at seven and took an electric bath, for which the current used was.....	.3333
Heated bedroom for half hour with electric stove	.5000
Heated water for shaving on electric stove	.0333
Used electric boot cleaner	.0133
Pressed trousers with electric iron	.0400
Ironed silk hat with electric ironer	.0333
Kneaded dough for a loaf of bread with electric kneader	.0066
Boiled a pint of coffee on electric stove..	.0666
Cooked a chop by electricity	.0666
Aired my room with electric fan	.0238
Turned on electric piano while I ate my breakfast	.0500
Cleaned the knives and forks with electric cleaner	.0010
Polished the plates with electric polisher	.0050
Curled my mustache with electric curling iron	.0025
Lighted a cigar with electric lighter	.0003
Rode in electric elevator to the basement	.0033
Drove my Waverley electric 4½ miles to the bank	1.0000
Total k. w. hours	2.1789

For which I pay 10 cents per hour, or 22 cents in all. This does not take account of the current used in my electric clock, but as a single k. w. hour will keep that running for ten years, it seems safe to disregard the clock."

After this, who will question the economy of electric power?

The 5000 h. p .Pelton-Francis turbine built in the San Francisco shops of the Pelton Water Wheel Company and intended for the Utah Light & Railway Company's Weber Canyon power plant is ready for shipment. This turbine will be direct connected to a Western Electric alternator running 360 r. p. m., the combined machines supplying power for the Salt Lake City electric tramway system. Special importance is attached to this turbine because of its size. The effective water head is 138 feet, and owing to the long pipe line supplying same with water, the turbine regulating mechanism has received special care in design. The pipe line tapers from 84 inches to 74 inches, terminating in a special wicket gate on the turbine having a 67-inch diameter inlet. The regulation will be effected by a Pelton special oil pressure governor actuating the bronze wicket gates. The latter are mechanically connected to a special 32-inch Pelton relief valve for preventing undue pressure rise in the pipe line should severe load fluctuations occur causing the governor to instantly close the wicket gates. The turbine is of the double, inward flow, reaction type, the casing alone exclusive of the draft elbows and pipe connections, weighing some 25 tons. A detailed description of this most interesting equipment will appear in the Journal at a later date.

BOOKS RECEIVED.

Practical Lessons in Electricity. By F. B. Crocker, L. K. Sager, H. C. Cushman; 238 pages; 7x10. American School of Correspondence, Chicago, Ill.; Technical Book Shop, San Francisco, Cal. Price, $1.50.

A number of instruction sheets issued by the American School of Correspondence have been here bound together in one volume for convenient reference. This book is intended for purposes of instruction and home study, and is based upon those methods which have been used by the correspondence schools. The text is divided into five sections devoted respectively to elements of electricity, electric current, electric wiring, electric bell-wiring and storage batteries. There are numerous diagrams and illustrations supplementing the written text.

Theoretical Elements of Electrical Engineering. By Charles P. Steinmetz; 3d Edition, 455 pages; 6x9. McGraw-Hill Book Company, New York City, and the Technical Book Shop, San Francisco. Price, $4.00.

Within the past few years there have been placed upon the market electrical apparatus involving principles of alternating currents that are not generally understood, such as the variable speed single phase motor. The electrical engineer already familiar with the early editions of this work will therefore welcome a new edition, thoroughly revised and corrected and containing sections on short-circuit currents between machines operating in parallel and in alternators and turbo-generators; commutation, commutating poles and alternating current commutating motors; the synchronous converter, split pole converter and motor converter; the three-wire generator; regulation and stability and synchronizing induction motors. After an introductory outline of the general theory of alternating currents covering one hundred and nineteen pages of explanatory text, the author takes up special apparatus in accordance with the classification adopted by the A. I. E. E. Standardizing Committee. These include synchronous motors and generators, direct and alternating current commutating machines, synchronous converters and induction machines. The treatment includes a description of the most advanced practice in the construction of alternating current machinery and is especially valuable to motor users.

Metallurgy of the Common Metals. By Leonard S. Austin. Second Edition; 500 pages; 195 illustrations. Mining & Scientific Press, San Francisco. Price, $4.00.

The student of metallurgy will welcome a second edition of Professor Austin's excellent work, which has already been adopted as a text by several of the mining colleges. This volume brings into compact form the essential features of the winning and refining of the common metals, namely: gold, silver, iron, copper, lead and zinc. The author has enriched the text with results of, not only his years of teaching, but also his years of practice, particularly in the treatment of silver ores. The book is subdivided into eleven parts. The first is general in character, and includes valuable information on thermochemistry, the heat absorbed or liberated by chemical combination. Sampling and crushing are also treated here. Succeeding parts are concerned respectively with the metallurgy of the ores of gold, silver, iron, copper, lead and zinc. This is followed by a description of the methods of refining them. The concluding chapters on commercial considerations is especially valuable, including organization, operation and cost of a metallurgical establishment. All theoretical discussions of processes are supplemented by illustrations from practical work. The treatment closely follows the usual course of lectures given to mining students, and is admirably adopted for home study by any one conversant with the rudiments of chemistry. The space devoted to the subject of concentration is limited, it apparently being beyond the province of this volume. The sections devoted to the cyanide of gold ores and to the calculations of smelting changes is unusually complete.

"Radiation, Light and Illumination." By Chas. P. Steinmetz; 305 pages. 6½x9½; 127 illustrations. McGraw-Hill Book Company, New York City; Technical Book Shop, San Francisco. Price, $3.00.

The study of light and analogous energy radiations from an engineering standpoint is novel. By applying logical principles and by minimizing mathematical formulaism the author develops matter of great interest and value. These lectures were originally given as a course of instruction to students of electrical engineering at Union University. While primarily a text book on illuminating engineering it will be found of universal interest, as we are all users of light. The lectures are thirteen in number. The first five are concerned of the phenomena of radiation, showing that radiation from alternating currents, electric surges, the wireless telegraph, Hertzian waves, heat, light, ultra-violet, and the X-ray differ only in frequency, which for convenience are divided into two classes the electric waves and the light waves. After an introductory explanation of the nature of radiation and its various forms and its behavior in different bodies, the discussion is devoted to its effects—physiological, chemical and physical. The succeeding chapters treat of illuminiscence; flames as luminants; arc lamps and arc lights; measurement of light and radiation; light flux and distribution; light intensity and illumination; illumination and illuminating engineering and physiological problems of illuminating engineering. This is a book that will repay close study, as it contains much information not found elsewhere, and gives a theoretical and scientific basis for the profession of illuminating engineering, of which this text is at once the most ambitious and satisfactory in the field of lighting literature.

Direct and Alternating Current Testing. By Frederick Bedell; 265 pages; 5½x8½. D. Van Nostrand Company, New York City, and the Technical Book Shop, San Francisco. Price, $2.00.

This book is an improvement over the usual laboratory manual in that it explains reasons and interprets the results of the various tests for which directions are given. These directions and interpretations are so concise and so lucid that they give to the reader an excellent comprehension of the principles of dynamo electric machinery. This is particularly noteworthy in the chapters on alternating currents. Its use as a reference text is greatly facilitated by a good index. The book is divided into seven chapters, each containing two or three sets of experiments. The first chapter on direct current generators, after a brief introductory statements of principles, explains in detail the method of determining the characteristics of series and compound generators. The second chapter deals likewise with shunt, compound and series direct current motors, together with efficiency tests. The method of obtaining the characteristics of synchronous alternators, both by testing and by predetermining, are discussed in full, including both the electric-motive force and the magneto-motive force methods. The chapter on single phase alternating current contains a clear explanation of the calculation and measurements in circuits, including the circle diagram. The chapter on transformers makes plain in a simple manner many ambiguous points. After a general study the author describes and compares the various methods of measuring power. The concluding chapter is devoted to phase changers and potential regulators. The experiments selected are those which have proven most effective in developing an understanding of principles, and are intended not as a set of standard tests, but rather as a means of clarifying the principles involved. Similar treatment of induction motors and converters would add materially to the value of the work.

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FOUNDED 1887 AS THE
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Station Records

A sure index of an engineer's capability is given by his log. The facts show what he is doing, and his manner of keeping it tells much as to his character. The keeping of records is therefore something in which every power-house engineer should perfect himself, as he can never tell at what time they may be produced as a witness of his fitness. These records are intended primarily for comparison, to determine the cost of generating power and to act as a check on waste. Properly plotted they give a graphic idea as to the workings of every department of a great industrial organization.

Of the various power plant records, switch-board, engine and boiler room and distributing system, the first are perhaps the most important, as they measure the power output. Various devices have been perfected that automatically record all variations in volts, amperes and watts, which save much time that might otherwise be consumed in manual recording. These figures are of particular use in determining the form of the load curve.

From the engine and boiler room records, as compared with those of the switchboard, can be determined the losses in producing the power, just as the distributing records show the losses in its delivery. Indicator diagrams from the engines are necessary to determine the condition of the valves. Accurate records should also be kept of labor and supplies, and especially of repairs, in order that the station costs may be figured on a uniform basis. Boiler room records should include the amount of fuel and water used, together with the steam gauge record, and frequent flue gas tests as a check as to whether the firing is being well done.

These are facts with which every engineer is familiar, and yet this very familiarity sometimes breeds contempt. The records are valueless unless kept continually. By studying them, there is many a waste that can be eliminated and the efficiency of the station thus increased. In order to keep his job the steam engineer should be able to show that he is furnishing power from his equipment as cheaply as can be done by some one else, and as economically as can be obtained from some some other source. It is only by keeping accurate account of his costs and getting good service from his plant that he can insure freedom from worry as to the security of his own position.

The Romance of Engineering

It is a matter of current comment that the life of an engineer is an unromantic one; that the deadly monotony of his work tends to blunt his finer sensibilities. While we must admit that it is not a particularly exhilarating task to hold the speed indicator on an engine or to watch a weir, and that is is not conducive to the development of the imaginative faculty "to determine the maximum number of blisters that can be placed upon the thumb by the ring end of a steel tape," yet the same may be said of almost any other kind of work that fits for higher things. It is only through the apprenticeship of drudgery that the master workman is developed.

The main essential is not to become a mere time server while learning the necessary rudiments, but rather keep the mind receptive to new ideas, and observe the possibilities for improving old methods. In this age of action and energy there seems to be a tendency to neglect that old-fashioned virtue of occasionally thinking of something beside the humdrum of work. The engineer that allows his work to run him, who goes to his home so preoccupied with his difficulties as to neglect his family ties, is not living, but merely existing.

There is, perhaps, no better way of illustrating our meaning than by referring the reader to some of the writings of Kipling wherein he deals with the romance of the commonplace. He shows us the romance of everyday life, of commerce and of machinery. Refuting the idea that every new invention or discovery tolls the knell of romance, he tells of the pleasures of the locomotive and marine engineer who can lighten his work with an apreciation of the beauty, wonder and love for life, "though there arn't a wave for miles and miles excep' the jiggle from the screw," yet the fascination of seeing the world keeps him satisfied with his work.

What is more inspiring than the tremendous speed now attained by the aid of power! What finer theme could poet want than the flight of the aeroplane! How puny are the imaginative wonders of the "Arabian Nights" as compared with the wonders of power where coal is the imprisoned genii. The marvels of electricity were far beyond the greatest stretch of their imagination.

The great trouble with most of us is we do not see beyond the end of our monkey-wrench. It is not necessary to become idle dreamers, but a little exercise of our imagination, an occasional study of the ideal, will raise us from the rut of the commonplace and remove that stigma of being unromantic.

The Power of Public Opinion

This journal has published many articles upon power; the power of electricity, of steam, of water, of gas and of air, but their effectiveness pales into insignificance if the development is not endorsed by the power of public opinion. Throughout the course of all history the real "power behind the throne" has been public opinion. Every government that has run counter to its trend has been overthrown, but the leader who trains his aero-plane to its dictates is carried to the highest pinnacles of success.

One ampere of electric current is of little avail without the volt that gives to it the power of the watt. One molecule of gas is inert until dissociated by the electric spark. One cubic foot of steam without pressure can do little work. A single drop of water on the ground is a weak thing, yet united with multitudes of its kind, and given the advantage of a difference in elevation it can sweep aside everything in its path. Thus it is with public opinion—given motion and number it is irresistable. These qualities are imparted by the gradual realization of wrongs, and are liberated by sudden sense of indignity. The machinations of lawyers and politicians can no more stem the flood than can the utmost contrivance of the engineer stop the force of a broken dam.

All power without proper guidance vents itself in destruction. If led through proper channels it is capable of beneficial utilization. Public opinion is guided largely by the great minds in its midst who sway it as they will, until some stronger, and perhaps better, influence attracts it to a new path. For the opinions of even the best of men may be wrong and require but the pointing of the right to be changed.

For years many communities suffered under various forms of graft. Recently the prosecution and punishment of the wrong doers gave relief. But in such instances as where prosecution became persecution, where the real criminals were set free in order that the personal spite or aggrandizement of the prosecuting agent might be fulfilled, the revulsion of feeling has been as marked as its former action.

Today certain strangers who do not appreciate the needs of the West are fostering a sentiment of forest and water hoarding under mistaken ideas that they are thus conserving natural resources. In judicious moderation conservation is greatly needed, but when it will retard the industrial development of the country, leave undeveloped its latent resources, the people dwelling in those communities should suggest that their law makers conserve conservatively. It may take time for this sentiment to grow, but the power of public opinion will finally make itself felt.

PERSONALS.

B. F. Kierulff of Los Angeles was in San Francisco this week.

George W. Belden Jr. is now manager of the Standard Electrical Works, vice F. H. Woodward, resigned.

F. F. Skeel is on his annual Pacific Coast trip in the interest of Crouse-Hinds Company of Syracuse, N. Y.

O. W. Lillard, Pacific Coast manager of the Gould Storage Battery Company, returned from a trip to the East last Monday.

H. G. May, president of the Sacramento Electric Supply Company, sailed this week for a three months' pleasure trip in the Orient.

W. W. Briggs, manager of the San Francisco office of the Westinghouse Electric & Manufacturing Company, left for Honolulu this week.

J. W. Ricketts, having completed the transmission line of the Arizona Power Company, near Prescott, is now at his home at Oroville, Cal.

W. J. Foster, designing engineer of alternating current machinery for the General Electric Company of Schenectady, N. Y., arrived in San Francisco last week.

F. V. T. Lee, assistant general manager of the Pacific Gas & Electric Company, is absent on a two months' sea voyage. He will return from Australia early in January.

R. E. Frickey, electrical engineer, Northern California Power Company, Redding, Cal., has been elected an associate member of the American Institute of Electrical Engineers.

P. H. Hillebrand, division foreman, Marysville Power Division, Pacific Gas & Electric Co., is now an associate member of the American Institute of Electrical Engineers.

H. C. Rice, sales engineer with the Seattle office of the Westinghouse Electric & Mfg. Co., was recently elected an associate member of the American Institute of Electrical Engineers.

H. B. Rutledge, construction foreman for the General Electric Company, Union Trust Building, San Francisco, was elected an associate member of the American Institute of Electrical Engineers, on November 12.

F. H. Woodward has resigned as manager of the Standard Electrical Works, San Francisco, to accept the position of power salesman for the Great Western Power Company, with offices in the Shreve Building, San Francisco.

H. A. Barre of the Electric Operating Construction Company, who have just completed the plant of the Arizona Power Company, which furnishes power to the United Verde mine at Jerome, and the city of Prescott, Arizona, was in San Francisco the latter part of last week. He is returning from an extended trip in the Northwest.

N. Samwell of Burmah, India, spent the last two weeks in San Francisco, making an inspection of the California dredging fields. Mr. Samwell is engineer for an English syndicate controlling large dredging interests in the Far East. They contemplate purchasing ten large gold dredgers, the power of which will be furnished by Pelton water wheels.

THE CALIFORNIA STATE ASSOCIATION OF ELECTRICAL CONTRACTORS.

On October 19th, 1909, electrical contractors from various places in California, including from San Francisco, Los Angeles, San Diego, San Jose, Sacramento and Oakland, met at dinner in the private dining room of the Hotel Argonaut, San Francisco, for social intercourse and for further purpose of considering the question of organizing a State Association of Electrical Contractors. The persons, firms or corporations represented included Woodill & Hulse Elec. Co., of Los Angeles; Southern Electrical Co., of San Diego; E. C. Wakeland, of Oakland; R. W. Meyers, of Fruitvale; W. W. Hanscom, president of the San Francisco Branch of the National Electrical Contractors' Association; Chas. E. Wigkin, treasurer of the San Francisco Branch of the National Electrical Contractors' Association; Hanbridge-Loyst Elec. Co.; Latchem Engr. & Elec. Co.; Levy Elec. Co.; National Elec. Co.; Centruy Elec. Co.; Standard Elec. Con. Co.; Butte Engr. & Elec. Co.; California Elec. Con. Co.; Central Elec. Co.; Independent Elec. Con. Co.; McFell Elec. Co.; Electrical Supply Co., of Sacramento; Jerome N. Bachman; E. A. Brooke Ridley; F. V. Meyers, secretary of the San Francisco Branch of the National Elec. Contractors' Association, and others.

After discussion temporary organization was effected, and committee on permanent organization and by-laws was appointed. The meeting then adjourned to meet again on the following day at the same place.

On said following day and still again on October 21st, the said contractors met again, all with result that on the last said day the permanent organization of "The California State Association of Eletcrical Contractors" was accomplished by the adoption of a code of by-laws and the election of the following officers: W. S. Hanbridge, President; W. B. Woodill, First Vice President; C. H. Heilbron, Second Vice-President; F. V. Meyers, Secretary-Treasurer; E. C. Wakeland, Sergeant-at-Arms.

The Association has a roll of approximately 60 members throughout the State of California. Districts are being organized in the principal cities and towns, pursuant to plan named in the by-laws and organization is being earnestly carried forward. It is believed that within a very short time the organization will be in a position to greatly benefit its members in every direction. Its policy is intended to be conciliatory toward all opposing interests, while at the same time vigorous in protecting and advancing the interests of its members.

F. V. MEYERS,
Secretary-Treasurer.

TRADE NOTES.

Arthur B. Lebenbaum and Edwin B. Pike, formerly in the electrical contracting business, are now permanently located in the Wiley B. Allen Building, 135-153 Kearny street, San Francisco. The firm of Pike & Lebenbaum are the Pacific Coast representatives for The Alliance Specialty Manufacturing Company.; Betts & Betts, Inc.; The Brilliant Electric Company. The A. E. Rittenhouse Company; The Tungstolier Company, etc.

The Seattle office of the Telephone-Electric Equipment Company has closed a contract with the Farmers' Mutual Telephone Company of Lynden, Washington, for a complete central energy telephone plant. The switchboard is the two position, non-multiple type, with an ultimate capacity of 280 C. E. lamp lines and thirty pairs of cord equipments. The initial equipment will cover eighty C. E. lamp lines and thirty self-restoring drops for rural lines. The necessary power equipment is included in the sale, and entire installation is to be connected and ready for operation within sixty days.

J. G. White & Company, Inc., engineers and contractors, 43 Exchange Place, New York, have been awarded the contract for the double tracking of the Albany Southern Railroad between Rensselaer and Kinderhook Lake, N. Y., as well as the straightening of curves and the rehabilitation of a large amount of the present track of that company. In addition to the operation of its third rail electric road between Albany and Hudson, N. Y., the railroad company furnishes electric light to a number of towns, and also owns and operates gas plants in Hudson and Rensselaer, N. Y. The above properties are under the management of J. G. White & Company, Inc.

INDUSTRIAL

THE UTILITY ELECTRIC IRON.

Among the orange groves of Southern California in the town of Ontario, forty miles east of Los Angeles, the Pacific Electric Heating Company is building a business that has already become national in scope. In addition to the famous "Hot Point" electric iron, this company manufactures a number of other electrically heated appliances. During the present season it has introduced two radically new features—an automatic type of iron and a very light iron called the "Utility" which also heats the curling tong and is used as a disc stove.

The accompanying illustrations show this "Utility" iron

Unpacking Utility Iron.

Ironing With a Utility Iron.

in various uses. It weighs only 2½ lbs., including cord, switch plug and attachment plug, and packed in an ooze leather bag with a dish, handle and stand, the whole combination tips the scale at exactly 3½ lbs. It will be seen that this is therefore a traveler's iron in the best sense of the word but by no means restricted to that use.

Actual tests have proven that this iron has good ironing capacity and it will do the ordinary household ironing without a bit of trouble. Inspection shows that this iron is made after the well known Hot Point Iron principle—that is, there are two heating elements running along the sides of the iron and coming together at the point. This arrangement lends extra heat to the point of the iron so that when the iron is not in use it is of greater temperature than the rest of the ironing surface. But when the iron is put into service the cold damp goods brings the point down to the temperature of the rest of the iron and holds it there. This means that the operator can iron right up into the tucks and plaits of the garment. The principle applies to the whole line of irons made by the Pacific Electric Heating Company.

The other innovation introduced by this company was their automatic iron which consists of a device built into the iron whereby when the working surface becomes over-heated the current is automatically cut off. This principal has proven so entirely successful that it has been now applied to all of the laundry irons which includes irons from 7½ lbs. up. This also applies to the 6 lb. size.

This industry was started in a comparatively small way several years ago by Mr. E. H. Richardson, under whose personal supervision the present line of irons have been developed. The success of this company is an excellent demonstration of the point that there is an opening in this territory for plants to manufacture a great many of the products which we are importing regularly from Eastern centers. In fact, the Pacific Electric Heating Company has been enabled to "carry coals to Newcastle" by building up a very substantial business in Eastern centers. Probably the most conspicuous thing of this kind that has been done was a shipment of a solid carload of Hot Point irons to the Commonwealth Edison Company of Chicago.

Ontario, where these irons are manufactured, is a charming village among the orange groves about forty miles east

Utility Iron as Water Heater.

of Los Angeles, and it offers opportunities for manufacturing under the most favorable conditions. There is a good supply of power at very cheap rates which is produced in the canyons a few miles north of the town. It is typical of the

Utility Iron as a Curling Tong Heater.

smaller industrial centers which are springing up in all parts of our veral Western country.

This company took the Grand Prize at the Seattle-Yukon-Pacific Exposition on its display of irons, which is the highest award given by the Exposition.

The city of Pasadena has completed the installation of an addition of 1000 kilowatt to the city power station, the equipment consisting of Westinghouse generator and switchboard. The former 500 k. w. unit was changed from 60 cycle to 50 cycle and 50 additional k. w. added. The general system has been largely extended in the last twelve months; 1500 poles were set, 200,000 lbs. of copper strung, and 1500 meters installed.

Rucker Brothers of Hartford, Washington, have recently largely increased the capacity of their sawmill. The new equipment consists of a complete installation of live rolls, lath machinery and blowers which they purchased of Allis-Chalmers Company. This firm also furnished a heavy duty twin horizontal Corliss engine. It will have cylinders twenty inches in diameter with thirty-six inch stroke running 100 r. p. m.

THE SLIDE RULE AS A WIRE TABLE.

By L. St. D. Roylance.

For the past several years articles have been appearing in the various electrical journals throughout the country, treating upon the subject of the slide rule as a wire table. I believe that I can safely say that I am the original discoverer of the relation of the table of properties of copper wire to the slide rule. My first discovery of the relation of the aforesaid properties and the slide rule, dates back as far as 1900, when I commenced using the rule for ascertaining the diameter, circular mil-area, square mil-area, weight per 1000 feet, and resistance per 1000 feet for copper and various resistance wires from 0° C. up to a temperature of 110° C.

About December, 1903, I had perfected my formula and also a model from which Figs. 1 and 2 are taken. In September, 1904, I negotiated with Keuffel & Esser Co., New York, regarding the manufacture of rules with my improvements, also stating at the time my intention of patenting my improvements. In some manner my communication with Keuffel & Esser Co., had been accidentally misplaced by them and it was December 20, 1904, before I received a reply from them offering an apology for the delay. At the time my attention was taken up with other matters requiring my immediate attention, and I was obliged to neglect it for a time. I filed application for a patent on the rule, December 19, 1905, same being rejected June 1, 1906, owing to interferences pertaining to the mechanical construction, and it being held that the arrangement of the scales and the particular kind of data thereon is merely a matter of mathematical skill and does not involve invention.

Up to December, 1903, when I got my first model, I got all the properties from an ordinary Keuffel & Esser 5-inch pocket slide rule and also the ordinary 10-inch rule, I used the upper scale of inches at the top edge of the rule for my gauge points.

As the B. & S. gauge sizes are nearly in geometrical progression, they fall very near ¼ inch apart on the 5-inch rule and ½ inch on the 10 inch rule. With a 5 in. rule start at 0 in., which point represents No. 10 size, each ¼ in. to the right represents a gauge number, therefore, ¼ in=No. 11, ½ in.=12, ¾ in.=13, 1 in.=14, and so on to the end of the scale of inches; 5 in.=No. 30. Gauge numbers 30 to 40, fall about 1/32 in .to the right of the ¼ in. divisions, and gauge numbers 0000 to 9, fall about 1/16 in. to the left of the ¼ divisions. For gauge numbers from 30 to 40, start No. 30 at 0 in. moving ¼ in. to the right for each size up to No. 40 which is located near 2½ in., and for numbers from 0000 to 9, start No. 10 at the right near 5 in. and move to the left reading backwards, 9, 8, 7, 6, 5, 4, etc., to No. 0000 which is located near 1¾ in. With a 10 in. rule the manipulation is the same, only the distance between the gauge points is ½ in. The variations from the ¼ in. and ½ in. divisions mentioned above will probably vary with the various rules, owing to the slight variation in mounting the inch scales.

A description of my improved rule and its operation follows:

Fig. 1 is a plan of the rule showing the general arrangement and manipulation of same for determining the values shown in wiring tables. Referring to the figure, it shows the left index of the C scale set directly under the hair line of the glass runner, which is in line with the index on the lower end of the runner which is set at No. 14 on the B. & S. gauge scale. On the C scale directly over the right index of the D scale, read 64 mils diameter, on the B scale directly over 64 of C scale, using runner read 4096 circular mils, on B scale directly under .7854 of A scale, read 3217 square mils area, on B directly under .003027 of A scale read 12.4 lbs. per thousand feet for bare copper wire, on A scale directly over 10000 of B scale, read 2.44 ohms per thousand feet at 10° C. or 50° F., over 10400 read 2.54 ohms per thousand feet at 20° C. or 68° F.

In the above example 10000 of the B scale represents the resistance of 1000 feet of 1-mil-diameter copper wire at 10° C. or 50° F. and each .1 division to the right or left equals 1% change in resistance or 2½° C. or 4½° F. change in temperature.

The above formula is based upon values taken from Dr. Matthiessen's table, which assumes that the resistance of one mil-foot of 98 per cent pure copper wire at 0 degrees C. equals 9.59 ohms, and the temperature coefficient of same at and from 0 degrees C. equals .0042, and at and from 10 degrees C., the resistance is 9.993 ohms with a temperature coefficient of .004031.

It will be noted above that the resistance per mil-foot at 0 degrees C. is taken slightly higher (9.6 ohms), and at 10 degrees C. (10.00 ohms), and the temperature coefficients are .00417 and .004 at and from 0 degrees C. and 10 degrees C. respectively. On comparison it will be found that for most all practical purposes, the factors will be sufficiently accurate and the discrepancies will hardly exceed the variations of the wire diameters and errors in practice of reading testing instruments, etc. They are practically correct for variations of temperature up to 100 degrees C., at which point they will be found correct in comparison with the American Institute of Electrical Engineer's formulas, as the following examples will show:

The scale mounted in the center of the base of the rule below the slide as shown by Figs. 1 and 2, is a table containing the carrying capacity in amperes for wires and cables which is adopted by the National Board of Fire Underwriters. The first or upper scale of figures represents the amperes current allowed for rubber covered wires from No. 18 to 000 B. & S. gauge, the second scale of amperes for weatherproof wires; the third and fourth scales for rubber covered and weatherproof cables, for which the gauge numbers read hundred thousand circular mils; that is, No. 10 represents 1,000,000 cm., 14 equals 1,400,000 cm., 2 equals 200,000 cm.

Fig. 2 shows the method of ascertaining the carrying capacity of wires and cables. The runner is set at No. 8, which reads 33 amperes for rubber covered wire; 46 amperes for weatherproof; 550 amperes for 800,000 cm. rubber covered cable and 840 amperes for 800,000 cm. weatherproof cable.

Other features are embodied in the construction of a glass runner in combination with a segmental lens for magnifying the faces of the scales; thereby enabling much closer readings, also the dimensions of the glass runner are such that the distance from the hair line center to the sides of the frame are equal to the distance from .7854 to 1 on the A and B scales and parallel to the hair line. The advantage of such construction is that the right hand edge may be placed at any diameter on the D scale and the square area read directly

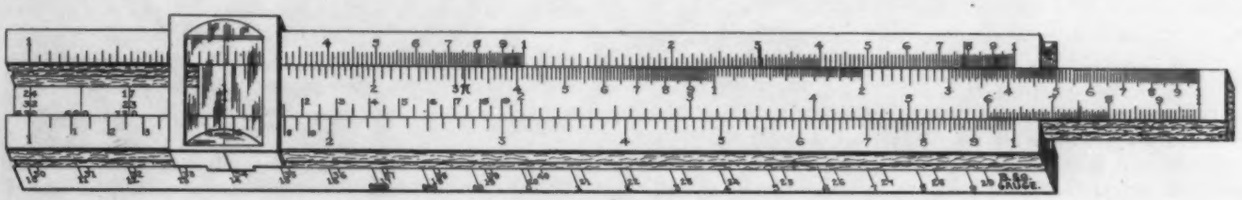


FIGURE 1.

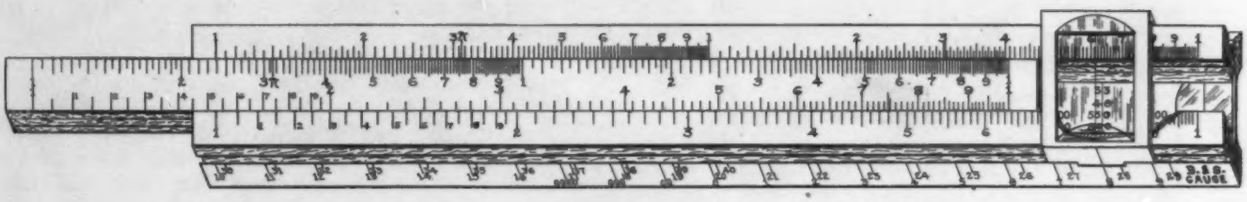


FIGURE 2.

Example 1: R at O° C. = 383.6 Ohms; required R_t at 100° C.?

By formula, $R_t = 383.6 \times (1 + 0042 \times 100) = 560$ Ohms.

By rule, R_t = Set 9600 of "B" to 383.6 of "A", then read to the right along "B", remembering that each .2 division equals 5° C. and directly over 1400 of "B", read 560 ohms on "A" scale.

Example 2; The resistance of a field coil at 10° C. is 80 ohms, after a heat test is found to be 85 Ohms; (a): What is the temperature? (b): What is the temperature rise?

(a). By formula, $T_h = 238.1 + 10\ (\frac{85}{80} - 1) + 10 = 25.5°$ C.

(b). By formula, $T_r = 238.1 + 10\ (\frac{85}{80} - 1) = 15.5°$ C.

(a). By rule, T_h = Set 10000 of "B" under 80 of "A" and under 85 of "A", read 25.5° C. on "B". In reading temperature, start at left index of "B", which represents 10000 or the cold temperature 10° C. and read to the right, each .2 division equals 5° C. or 9° F.

(b). By rule, $T_r = 25.5° - 10° = 15.5°$ C.

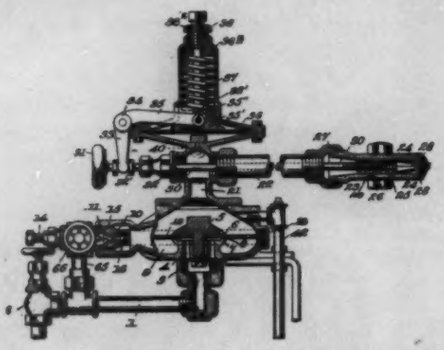
Referring again to Fig. 1 it will be readily understood that these properties may be read directly from the rule for wires or conductors of any diameter and of any metal or alloy; all that is necessary is to place the diameter of the wire on the C scale directly over the right or left index of the D scale and read the result. For metals and alloys other than copper, the ratios of weight and resistance to copper must be known and constants established.

at the hair line on the A scale; also the area of a circle being given, the diameter is immediately determined by setting the left hand edge to the area on the A scale and the circle diameter is read at the hair line on the D scale. Any number may be multiplied or divided by .7854 by setting the hair line to the number on either the A or B scale, to multiply, read at the left edge; to divide, read at the right edge. The above operation is performed much quicker with the runner mentioned and described, requiring less effort than the old method of moving the slide and the runner also to obtain the same result.

The San Joaquin Light & Power Company have placed an order with the General Electric Company for the following material: Two ATB-18-4000 k. w. 400 r. p. m. 2300 volt water wheel driven generators, one 100 k. w. motor generator exciter set consisting of one MP-6-100 k. w. 900 r. p. m. 250 volt, shunt wound generator driven by one type I-8-150 h. p. 900 r. p. m. 2300 volt induction motor and also one Doble water wheel. One MP-6-100 k. w. 900 r. p. m. 250 volt generator driven by a Doble water wheel; six type WC-60-1500 k. w. 20,050/34700y/40,100/69500y/2300 volt transformers. Switchboards for the above. Doble water wheels are used for all the above. The J. G. White & Co. are the engineers in charge of the above installation.

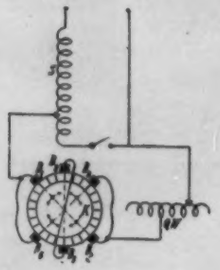
PATENTS

940,539. Automatic Oil-Burner. Arthur H. Light, Los Angeles, Cal., assignor to A. H. Light Engineering Company. Los Angeles, Cal. In an automatic burner, the combination of a mixing chamber for hydrocarbon fuel; a cylinder; a damper; connections between said cylinder and said chamber;



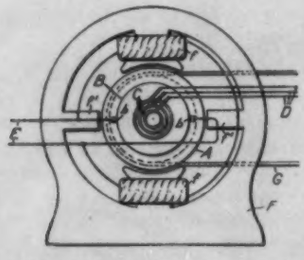
connections between said damper and said cylinder; a burner nozzle connected to said chamber; and means to control the outlet of said nozzle and thereby vary the presssure in said chamber and cylinder.

940,492. Arrangement for Regulation of Speed of Compensated Single-Phase Motors. Engelbert Arnold, Karlsruhe, Germany, and Jens L. La Cour, Vesteras, Sweden. In a compensated alternating current motor, in combination, a stator winding, a rotor winding having a commutator, brushes bear-



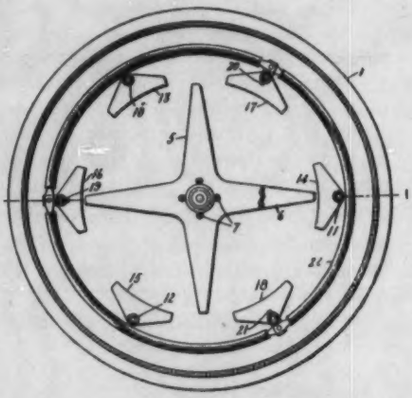
ing on the commutator arranged to form with the rotor winding exciting and compensating circuits, and means whereby the amount of rotor winding included between the brushes of the exciting circuit may be varied without changing the direction of the magnetic axis of the compensating circuit.

940,210. Dynamo-Electric Machine. Charles P. Steinmetz, Schenectady, N. Y., assignor to General Electric Company. A dynamo-electric machine having an armature provided with a commutator and collector rings, electrical connections to said commutator and collector rings whereby motor



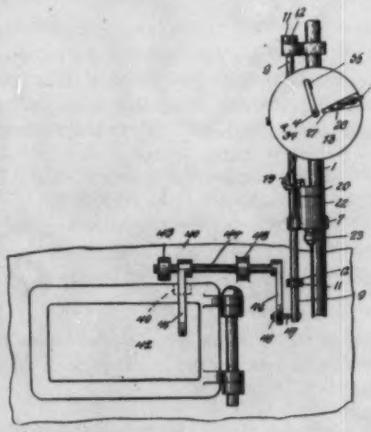
current is delivered to and generator current taken from the armature, the armature ampere turns due to the current through the collector rings being in excess of the ampere turns due to the current through the commutator, and unwound commutating poles located at the points of commutation of the current flowing through the commutator.

940,578. Protective Device for Electric Circuits. Sven R. Bergman, Lynn, Mass., assignor to General Electric Company. In a lightning arrester, a rotary member having a plurality of conducting arms, a plurality of contact plates in proximity to said arms but each having an angular width less than the



angular distance between adjacent conducting arms, a second rotary member having conducting arms, a second set of contact plates co-operating therewith, means for continuously moving said rotary members, and means for permanently connecting one set of said contact plates to the line to be protected.

940,050. Automatic Shut-Off. James F. Parker, Pittsburg, Pa., assignor to Pittsburg Automatic Smoke Preventor Company, Pittsburg, Pa. In an automatic shut-off, the combination with a pipe, a valve carried thereby and provided with an elongated stem, of a drum loosely mounted upon said stem and having two compartments formed therein, a counterpoise located in one of said compartments, a needle valve



arranged between said compartments, a flanged collar carried by said drum, lugs carried by said drum, an arm carried by said valve stem and adapted to engage said lugs, an actuating rod movably supported by said pipe, a chain connection between said collar and said actuating rod, and a dash pot supported by said pipe and having a plunger connected to said collar.

NEWS NOTES

FINANCIAL.

HOLTVILLE, CAL.—The proposition of $37,000 bonds for the acquisition of a municipal water system has been carried.

DAYTON, N. M.—Citizens and property owners have met and unanimously voted to issue bonds for installing a water system in this town. The City Council will take the matter up.

LOS ANGELES, CAL.—The City Council has passed a resolution authorizing $3,500,000 to be issued in bonds for constructing works for generating and distributing electricity for purpose of supplying the city with light, power and heat.

CENTRAL POINT, ORE.—The water bonds were received from the buyers, S. A. Kean & Co., of Chicago, and were signed up by Mayor Leever and Recorder Jones and turned over to the bank for collection. The issue is for $25,000 and the bonds are in denominations of $500 each, redeemable in 30 years. T. W. Osgood, city engineer, is rushing work on the plans for the distributing system, and will advertise for bids within a week.

INCORPORATIONS.

OKANOGAN, WASH.—Okanogan Telephone & Telegraph Company of Okanogan, by C. E. Hansen, president.

LOS ANGELES, CAL.—Long Beach Electric Company, capital stock $10,000, by G. D. Sweetland, M. L. Gunsul and P. Gunsul.

NORTH BEND, WASH.—North Bend and Eastern Railway Company of North Bend, by W. C. Weeks and R. W. Vennegde.

FRESNO, CAL.—W. M. & M. Oil Company, capital stock $100,000, by M. L. Woy, W. W. and A. T. Machen, M. Madsen and D. A. Cashin.

HAMILTON, MONT.—The Montana Independent Telephone Company has filed articles of incorporation with a capital stock of $1,500,000.

LOS ANGELES, CAL.—Incorporated, Anaheim Eucalyptus Water Company; capital $24,000; directors, S. Davis, E. S. Kornfeld, A. W. Allen, etc.

NORTH YAKIMA, WASH.—Priest Rapids Water Corporation, of North Yakima, Wash., $41,600, by R. J. Logan, J. H. Logan, J. H. and M. B. Rose.

SANTA FE, N. M.—Incorporated, Montana Power & Irrigation Co., with capital of $100,000. Directors are: G. F. Flick, F. C. Wilson and J. A. Massie.

BAKERSFIELD, CAL.—Westside Water Company, capital stock $100,000, by J. M. Dunn, C. W. Beatty, W. H. Coons, C. S. Garfield, J. H. Osgood and others.

SEATTLE, WASH.—The Empire Land & Power Company has been incorporated by James F. O'Brien and Frederic B Chandler with a capital of $5,000,000.

RIVERSIDE, CAL.—Corona Mutual Telephone & Telegraph Company, capital stock $25,000, by J. B. Golch, A. Lindberg, O. M. Grizzle and Bonfoey; place of business, Corona.

FRESNO, CAL.—The Coalinga Water & Electric Company has been incorporated with a capital of $2,000,000, to supply water and power to Coalinga and the oil fields. The directors are W. C. Kerckhoff, A. C. Batch, K. Cohn and A. G. Weston.

TRANSMISSION.

NAPA, CAL.—An electric power line will be run to the Napa Soda Springs. Superintendent O. E. Clark of Napa, will have charge of the extension.

MABTON, WASH.—The City Council has passed an ordinance granting to the Yakima Valley Power Company a 15-year franchise for installing and operating an electric light system.

SAN FRANCISCO, CAL.—In place of the Russian Hill station the United Wireless Company is planning to construct a new power station at a prominent point on the heights east of the Cliff House.

LOS ANGELES, CAL.—The date for the bond election for voting $3,500,000 for the development of the Owens river power and $3,000,000 for harbor improvements has been fixed at February 16th by the City Council.

GOLDFIELD, NEV.—A. J. Trumbo, general manager of the New Bonnie Clara Mining Company, has closed contracts with the Nevada California Power Company for electric power for the Clara mill at Bonnie and a line will be extended at once.

GEORGETOWN, WASH.—Robert M. Jones, Lowman building, Seattle, representing outside interests, has made application for a gas and electric franchise. Terms of proposed franchise call for completion of the plant within one year.

SHELLY, IDAHO.—The Gem State Light & Power Company has received a permit from the State to use water in the Snake river, two miles above Shelly, for use in a power plant, to cost $100,000, and to generate 8000 horsepower, which is in course of construction.

OTHELLO, WASH.—Under the name of the Othello Improvement Company, R. S. King, H. D. Moon et al. have organized a corporation capitalized at $500,000 for the purpose of erecting and operating electric light and water systems and drilling several wells for irrigation purposes.

SALINAS, CAL.—After several weeks of preparation the Monterey County Gas & Electric Company has changed over its two phase, four wire distributing system to a three phase, three wire system, sixty cycles, 2200-220-110 volts. The change was made on November 14 without accident.

GOLDFIELD, NEV.—Work is soon to commence on large power plants in Mono county, Cal., to supply power for an electric railroad from Coaldale to Bodie, to connect with the Tonopah and Goldfield Railroad, and also to furnish power for the mining camps of Southern Nevada and California.

CITY OF MEXICO, MEX.—The Guanajuato Power & Electric Company is preparing to transmit electric power to Aguas Calientes, where the American Smelting & Refining Company's smelter is located. Power will also be delivered to the Asientos and Tepezala mining districts of Aguas Calientes.

OAKLAND, CAL.—D. U. Toffelmire, representing the United Power Company, has applied to the Board of Supervisors for a franchise to erect poles and install a distributing system along the roads and highways of Alameda county. Toffiemire asked that the franchise extend the same privileges to the United Power Company as are enjoyed by similar corporations. The application was made for a franchise covering a period of fifty years, and Toffiemire asked that it be drawn and offered for sale to the highest bidder.

TELEPHONE.

LAMONT, WASH.—The Whitman County Telephone Company has filed articles of incorporation.

VANCOUVER, WASH.—The Heisson and the Cherry Grove Telephone companies are being formed.

YREKA, CAL.—The T. Jones Company has been granted permission to erect and maintain a telephone line along the public highway.

THE DALLES, ORE.—The United Wireless Telegraph Company has petitioned the city council for a permit to erect and maintain a station here.

BICKLETON, WASH.—The Farmers' Mutual Telephone Company of this place proposes to extend its lines to Mabton in Yakima county and Roosevelt on the Spokane, Portland & Seattle.

MOSCOW, IDA.—The farmers east of the city have organized the Tomer-Butte Telephone Company and will extend the line east 4½ miles. It will be a branch of the Moscow and Rural system.

GRANGEVILLE, IDA.—The mining districts tributary to the South Fork of the Clearwater river, will be brought into communication with Grangeville by a system now being constructed by S. C. McDaniels. The line will be about 100 miles long, including branches.

NAPA, CAL.—Antone Rossi having filed with the Board of Supervisors an application for a permit for a telephone line along the county road from the stone bridge near Spring Valley school house to the Rossi ranch, it was ordered that the application be granted.

MONROE, WASH.—The Commercial Club here is contemplating organizing a telephone service in the valley to operate from Monroe to Fall City. A committee was appointed at the last meeting to look into the matter and engage the services of a telephone expert.

ILLUMINATION.

SAN MATEO, CAL.—The Supervisors have issued a notice calling for bids for installing lights in the East San Bruno and Colma lighting districts.

LOS BANOS, CAL.—Within a few days the firm of Miller & Lux expects to install a new lighting plant in Los Banos. This will be a gas system in which gasoline is the chief fluid.

LOS ANGELES, CAL.—By an ordinance passed a few days ago property owners of territory in and adjacent to Sherman are empowered by the Supervisors to form a lighting district.

FOREST GROVE, ORE.—A franchise has been granted to A. Welch to furnish all night electric lights for Forest Grove. E. W. Haines has been supplying service, which has not been satisfactory.

SAN BERNARDINO, CAL.—It is announced that San Bernardino Valley Gas Company, which recently took over the Home Gas & Light Company, will commence work soon after the first of the year on a $200,000 central distributing plant at Colton.

LONG BEACH, CAL.—The Southern California Edison Company will build a substation in Belmont Heights district to care for the electricity that will be used in that section of the city, including lights used by residents and street lights to be ordered in by the city.

SAN DIEGO, CAL.—The City Council received but one bid for street lighting of this city. That will probably be accepted and was from the San Diego Consolidated Gas & Electric Company, which offers to furnish the required number of lights at the rate of $5 each a month.

TRANSPORTATION.

SAN DIEGO, CAL.—Bids are now being received for the $100,000 car barns which the San Diego Electric Railway Company is erecting.

FRESNO, CAL.—The Supevisors passed an ordinance granting the application of the Fresno Traction Company for a franchise to construct and maintain a street railroad.

EVERETT, WASH.—Permission has been granted the Everett Railway, Light & Power Company to lay a track from Forty-first street to the Southern line of South Park addition.

TACOMA, WASH.—The City Council is considering the building of a municipal street railway system to be completed by the time the power plant on the Nisqually is finished in two years.

OLYMPIA, WASH.—The Washington Water Power Company of Spokane, has applied to the State Land Office for a right of way across section 36, township 25, range 42 east, Spokane county.

EVERETT, WASH.—It is reported that the whole of the Cascade division of the Great Northern from Wenatchee to Everett will be equipped with electric engines, which will require an expenditure of $2,000,000.

MEDFORD, ORE.—The City Council at a meeting held recently granted to John R. Allen a franchise for an electric road in the city of Medford. The franchise covers all streets with the exception of Oakdale avenue.

LOS ANGELES, CAL.—The City Clerk will receive sealed bids up to December 21st for an electric line franchise commencing at the intersection of Main and Anne streets, thence northwesterly along Anne street to San Fernando street.

LOS ANGELES, CAL.—The City Council has passed an ordinance granting to the Los Angeles Railway Company the right to construct, and for a period of 21 years operate and maintain, a double track electric street railway upon certain streets in this city.

BOISE, IDA.—An electric line from Caldwell to Nampa by way of Deer Flat reservoir, will be built early next spring, the survey being completed about two weeks ago, and the material has been ordered from the East. The cost will be $150,000, including all rolling stock.

BELLINGHAM, WASH.—It is announced that the Stone & Webster interests will build an electric line between this place and Mt. Vernon, if the people of Skagit and Whatcom counties will advance $400,000 to the corporation. It is estimated that the 30 miles of road will cost $1,500,000.

ABERDEEN, WASH.—For the purpose of building a line of electric railway from a point on Puget Sound, which is declared to be Olympia to Hoquiam, Eldridge Wheeler, of Montesano, has made application to the Board of County Commissioners for a franchise along certain highways in Chehalis county.

ALBANY, ORE.—The Oregon Electric has filed supplementary articles, increasing the capital stock $10,000,000 and showing the lines to be built, one through Forest Grove to Tillamook, one through Dallas to Corvallis and Eugene, the main line through Albany to Roseburg, one from Dallas to Salem, one from Salem to Mill City, one from Albany to Cascadia.

NEW WESTMINSTER, B. C.—Word has been received in this city from Blaine to the effect that the Nooksack Valley Traction Company, which proposes building a line from Bellingham to the boundary line to connect with the B. C. Electric Railway to Vancouver, has completed the financial arrangements and expects to push forward the work of construction.